KEK Project Implementation Plan (KEK-PIP)

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KEK

1. Introduction

The High Energy Accelerator Research Organization (KEK) promotes research in fundamental science including particle physics, nuclear physics, materials science, and life sciences. For this purpose, KEK develops, builds, and operates state-of-the-art accelerators, and serves as a center of worldwide accelerator research. The KEK Roadmap 2013, released in May 2013 as a guideline for promoting research at KEK, was drawn up to advance this role of KEK further and to carry out high-profile research continuously at the forefront of worldwide fundamental science.

To proceed practically with the research projects set out in the Roadmap, an implementation plan must be developed making clear the funding sources and priorities. Particularly in the case of projects requiring large resources, new budget requests must be made. It is therefore necessary for these projects to be prioritized with a view to maximizing the outcome of KEK as a whole. The KEK Project Implementation Plan (KEK-PIP) has been developed for this purpose. While this Implementation Plan has the next six years in its scope, it must be revised from time to time based on progress in achieving the plan and new research results emerging inside and outside KEK. Moreover, since the current KEK Roadmap was created as an overview of the five years from 2014 to 2018, the need may arise to review this Implementation Plan as revisions are made to the Roadmap. The research projects discussed in the KEK Roadmap are classified into three categories, and their implementation plans are described in the following sections.

2. Three Major Research Projects

Of the research at KEK, J-PARC, SuperKEKB and Photon Factory (PF) are core KEK projects based on the large-scale accelerator facilities. Each of these research projects is authorized by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and is carried out with annually budgeted research funds. These projects need to be implemented according to plans and are expected to yield major accomplishments.

2-1 J-PARC

J-PARC (Japan Proton Accelerator Research Complex) is a multipurpose facility built around high-intensity proton accelerators. Studies cover a wide range of topics from the

fundamental laws of nature to the origins of life. It consists of the three experimental facilities, the Neutrino Experimental Facility, Hadron Experimental Facility (HEF), and Materials and Life Science Experimental Facility (MLF), as well as the accelerator complex, to cover diverse scientific fields. During the term of this Implementation Plan, KEK aims to take advantage of the high-intensity proton beams to produce scientific results with high impact. In particle and nuclear physics, together with SuperKEKB, research at J-PARC will be pursuing the high-intensity frontier complementing the high-energy frontier. For materials and life sciences studies, the facility will seek to improve the intensity and quality of neutron and muon beams. These, together with the synchrotron light source and positron facilities, provide a platform for studies of material structure combining multiple quantum beams.

Within the scope of J-PARC project funding, priority will be given to obtaining sufficient running time along with maintenance and improvement of the accelerator and experimental facilities. The budget also covers computer costs required in data analyses. In addition to these, we plan to cover the following five experimental apparatus within the J-PARC project budget: COMET Phase-I experiment, reinforcement of the facilities for T2K experiment, a neutron polarization analysis system, the central portion of the MLF muon beam H-line, and a high momentum beam line at HEF. The KEK Roadmap 2013 describes other new research projects to be carried out in addition to the above; these are introduced below under 4. Research Projects That Need New Funding.

2-2 SuperKEKB

SuperKEKB upgrades the peak luminosity to 40 times that of KEKB. It will enable Belle II experiment to acquire 50 times the data (50 ab^{-1}) of the previous Belle experiment. The Belle II experiment is expected to discover phenomena resulting from new physics beyond the Standard Model. Among these is CP violation with a new source, at the higher energy scale from the quantum effect, in the decay of B mesons, D mesons, and τ leptons. It will also become possible to identify new particle states formed by four or more quarks. The accelerator for this experiment is almost completed and is starting test operation. After tuning of the accelerator, the Belle II experiment is scheduled to begin in fiscal 2017.

Within the scope of funding for this project, priority will be given to securing running time and to improving the facilities so as to achieve the design performance in both the accelerator and detector. The budget also covers computer costs required in Belle II data analyses. It is further hoped to upgrade the Belle II electromagnetic calorimeter within the scope of this funding. Along with these steps, reinforcement of the RF system is

essential for increasing the beam current up to the design value. The budget for this purpose, however, will be considered when luminosity comes to be limited by beam current.

2-3 Photon Factory

The Photon Factory (PF) has been in operation for more than 30 years, contributing to leading-edge research in collaboration with universities and other research institutions. We will also continue with the stable provision of synchrotron light as an essential tool in materials and life sciences and support a wide range of research fields making use of it. Furthermore, KEK will play a pioneering role in the future development of synchrotron radiation science in Japan as a whole.

The insertion beam line, provided in the plan for improvement of the straight sections of the PF ring, is giving a powerful boost to research in many fields. These include strongly correlated materials, surface and interfacial physical properties, surface chemical reactions, and soft materials and functional polymeric materials. Another area is structural biology research by means of protein structure analysis. Along with the SuperKEKB upgrade, a new direct beam transport line is being installed for the PF-AR (Advanced Ring). This will enable low-emittance electron beams to be produced, which combined with top-up injections of 6.5 GeV direct beams will achieve greater beam intensity. As a result, it will be possible to conduct leading-edge materials research that was largely out of reach up to now. Examples are high-pressure X-ray diffraction measurement of minute crystal samples, and time-resolved X-ray measurement of dilute samples.

Within the scope of funding for this project, priority will be given to securing running time, while taking the minimum necessary measures to deal with deterioration and developing equipment and analysis methods.

3. Research Projects Carried Out Using Mainly General Funds

3-1 Research and development for the International Linear Collider

The International Linear Collider (ILC) is an accelerator project proposed by the international high-energy physics community. With the discovery of the Higgs particle at the LHC and the expectation of further discoveries hereafter, the ILC will enable clearer and more precise measurements of these newly discovered particles and phenomena. These measurements will be made in the center-of-mass energy region around 500 GeV, taking advantage of the features of a lepton collider. It will further our understanding of the mechanism by which electroweak gauge symmetry is broken. It

will also help in clarifying new laws of physics behind this mechanism, taking particle physics to an entirely new stage. Japan is already playing a major role in research and development on the ILC accelerator and detectors. Working with the Linear Collider Collaboration (LCC) of international scientists, KEK will proceed with development of the ILC superconducting RF cavities and accelerator-related technologies. In addition to R&D, KEK continues to make efforts to promote the ILC project with the Planning Office for the ILC established in February 2014.

KEK issued a KEK-ILC action plan in January 2016. In this plan it was proposed that the ILC project proceed in three phases: pre-preparation phase, preparation phase, and construction phase. The pre-preparation phase is the current phase, in which R&D in KEK has up to now been conducted mainly using general funds of KEK. As development advances, efforts need to be made to obtain external funding as well. The project will enter the main preparation phase when MEXT starts negotiations with other countries for implementing the ILC. At this stage an implementation organization will be set up centering around KEK to prepare for the construction over a period of approximately four years.

3-2. Other research projects carried out using general funds of KEK

The following projects have up to now been conducted mainly using general funds of KEK. They will be continued on the condition that greater efforts are made to obtain external funding.

- Simulation studies with the existing supercomputer (only up to summer of 2017)
- Industrial application of ERL technology
- Participation in CERN LHC/ATLAS
- Research carried out in the Detector Technology Project
- Research in the Japan-US cooperation program
- Projects under the Toshiko Yuasa Laboratory (TYL)
- Small-scale research projects conducted in KEK institutes

4. Projects That Need New Funding

4-1. New light source facility

With the existing light sources deteriorating and losing their competitive edge, it has become urgent to proceed with plans for the next light source facility. The KEK long-term plans have up to now called for a 3 GeV Energy Recovery Linac (ERL). This was made obsolete by the invention of the multi-bend achromat lattice as a synchrotron light source. As an alternative to ERL, a 3 GeV-class storage ring-type high-brightness

light source is seen as an appropriate replacement for the PF. This next-generation light source will achieve spatial resolution of the order of nanometers and energy resolution of the order of meV. It will make possible previously unachievable new research in several areas such as studies of the structural and electronic properties of heterogeneous substances, and clarification of chemical reaction dynamics that include fluctuations. KEK is starting specific consideration of an all-Japan effort to realize the high-brightness light source, which will become an indispensable tool for leading-edge research in a wide range of academic and industrial fields.

4-2. Prioritization of the remaining projects

Besides the research projects described above, the KEK Roadmap 2013 proposes research projects that, by striving for early realization, can contribute greatly to their respective research fields. Of these, the four research projects described below have been assigned priorities as shown in the parentheses, and budget requests will be made as appropriate. Note that upgrade of the power supply for the J-PARC Main Ring, which has been assigned the highest priority among budget requests for equipment, is not included in this list since the budgeting for this has been partially started already. Of the four projects, (3) and (4) have been proposed in combination with the J-PARC upgrade, which is already included on the MEXT Roadmap. Projects (1) and (2) were selected as part of the Science Council of Japan's Master Plan of Large Research Projects, with (1) being named as important large-scale research projects.

(1) Upgrading J-PARC for the Hyper-Kamiokande project

The next major goals in neutrino physics are to discover CP violation in the neutrino sector and determine the mass hierarchy. This will require a very large, high-sensitivity detector far exceeding Super-Kamiokande and long-term stable operation of a 1 MW-class high-intensity beam. The detector will at the same time play vital roles in the search for nucleon decay and in observation of atmospheric neutrinos. The Hyper-Kamiokande has been proposed and considered as a next-generation water Cherenkov detector for these purposes. KEK will be working in cooperation with the University of Tokyo's Institute for Cosmic Ray Research and others. KEK will, in particular, realize the over 1 MW-class high-intensity proton beam for the neutrino productions, which is a major key to success of the experiment and will also provide large potential for other physics programs.

(2) Particle physics in high-luminosity LHC/ATLAS

Raising the luminosity of the LHC through the 2020s will be of strategic importance for future energy frontier physics. It will become possible to search for new physics in gradually higher energy regions, as the integrated luminosity increases in proton-proton collision. While experiments on the existing LHC continue to be conducted, upgrades will therefore be undertaken of the accelerator and detectors. Building on the experience to date in LHC accelerator construction and the ATLAS experiment, KEK will carry out R&D for the upgrades and take part in the joint international construction efforts. For the accelerator, large-aperture superconducting dipole magnets in proximity to the collision point will be developed and constructed by KEK in consultation with CERN. For the detector, KEK will play a leading role in development and construction of the particle tracker, muon trigger and other components designed for high luminosity.

(3) MLF muon beam H-line and g-2/EDM experiment

Enhancement of the H muon beam line beyond the core portion will enable ultra-high-precision measurement of muon anomalous magnetic moment and electric dipole moment (g-2/EDM). The approach being taken differs entirely from conventional methods. It will take advantage of the intense beam to search for phenomena beyond the Standard Model. The beam line will further make possible precision muonium spectroscopy and transmission muon microscopy.

(4) Extension of the J-PARC Hadron Experimental Facility

The Hadron Experimental Facility will be extended with additional beam lines having performance surpassing that of existing facilities. The aim will be to enable multifaceted, concurrent advancement of major research efforts in the areas of nuclear and hadron physics and flavor physics. In proceeding with the facility extension, collaboration with other institutions will be sought, including RIKEN and the Osaka University Research Center for Nuclear Physics. Realization of this plan will make the Hadron Experimental Facility into a world-leading center of nuclear, hadron, and particle physics research, responding to the expectations of researchers throughout the world.

4-3. Remarks on computational physics research

Particularly in particle and nuclear physics, as the experiments become more precise and complex, the need has arisen for improvements in theoretical computing to enable

quantitative comparisons between the theory and experiments. Enabling precise calculations of physical quantities involved in experiments conducted at SuperKEKB and J-PARC, computational physics research will maximize the value of the results obtained from experiments. From this point of view, KEK will take possible actions to find a solution for providing appropriate computing resources to the research community, after terminating the lease contract of the present supercomputing system in September 2017.

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