# KEK Project Implementation Plan 2022

June 24, 2022

High Energy Accelerator Research Organization (KEK)

## 1. Purpose

High Energy Accelerator Research Organization (KEK) published KEK Roadmap 2021 in May 2021. It described in detail the status of research fields related to KEK and the strategy for the research program to be pursued at KEK in the future, focusing on the fourth medium-range goals/plans period, JFY2022–JFY2027. The Project Implementation Plan (PIP) 2022 was developed as a concrete implementation plan for the realization of the KEK Roadmap 2021, particularly from the viewpoint of funding resources.

## 2. Research Projects Authorized by MEXT

Among the many research projects at KEK, the following five projects are authorized and annually funded directly by Ministry of Education, Culture, Sports, Science and Technology (MEXT); Japan Proton Accelerator Research Complex (J-PARC), SuperKEKB/Belle II, Photon Factory (PF) and Photon Factory Advanced Ring (PF-AR), upgrading J-PARC for Hyper-Kamiokande, and High-Luminosity Large Hadron Collider (HL-LHC)/ATLAS upgrade. The most fundamental task of KEK is to advance each program to produce scientific outcomes efficiently. For this purpose, operating KEK's major accelerators for sufficient time to produce research outputs is a high priority in KEK's mission. The sustainable operation of accelerators is becoming an important issue for research laboratories because of the uncertainty of the cost of electricity, and careful monitoring and development of an appropriate operation plan are necessary. When allocating the annual budget within each project, priority will be given to securing operating hours rather than to performing maintenance and making improvements necessary for operation.

### 2.1 J-PARC

In the resource allocation for J-PARC, priority is given to securing the operation of the Main Ring for six months per year or longer in total for fast extraction (FX) and slow extraction (SX), followed by maintenance and improvement of the accelerator and three research facilities: Material and Life Science Experimental Facility (MLF), Neutrino Experimental Facility, and Hadron Experimental Facility. In JFY2022, the construction of

a new facility for the muon g-2/EDM experiment is to begin. It will be partially supported by KEK's discretionary budget. In the materials and life sciences at MLF, launching a new research project in the short term in response to social situations might be necessary, and a budgetary measure might be considered separately. COMET will be supported within the operation budget until the first phase is completed, and then second-phase construction will be considered, reflecting the progress in the first phase and considering international competition.

### 2.2 SuperKEKB

In the resource allocation for SuperKEKB and Belle II, priority is given to securing the operation of the SuperKEKB main ring for seven months per year or longer. Then, the SuperKEKB accelerator and Belle II detector will be maintained and improved. Among these, the research and development (R&D) necessary for the accelerator and detector to achieve the goal of search for new physics with an integrated luminosity of 50/ab will be pursued. Major upgrades scheduled for around 2026 will be carried out within the budget available for this project after clarifying the plan.

### 2.3 PF and PF-AR

In the resource allocation for PF and PF-AR, priority is given to securing the user machine time for 3600 hours or longer. Then, maintenance and improvement of the accelerators and beamlines of PF and PF-AR and measures against aging facilities will be made. A new budget request will be made for the R&D of the next-generation light source, as discussed in Section 8.

### 2.4 Upgrading J-PARC for Hyper-Kamiokande

An upgrade of the neutrino beamline and construction of the near detector will be performed according to the annual plan approved by MEXT.

### 2.5 HL-LHC/ATLAS Upgrade

The construction of the superconducting beam separation dipole magnet (D1) and the upgrade of the ATLAS detector will be performed according to the annual plan approved by MEXT. Concerning the increased contribution to the HL-LHC project expected by CERN, from the viewpoint of making a reasonable contribution from Japan, a new budget request will be made according to the priority discussed in Section 8.

## 3. Other Research Projects to Be Pursued by KEK

In addition to large-scale research programs, KEK has various small-scale research programs, as well as programs to support research. In this section, the programs that will be carried out using KEK's own resources are summarized.

### 3.1 Accelerator Development for Industrial and Medical Applications

This category includes the superconducting accelerator development that makes use of the Compact Energy-Recovery Linac (cERL) by the Innovation Center for Applied Superconducting Accelerator (iCASA) and the Ibaraki Boron Neutron Capture Therapy project (iBNCT). Both projects will continue, because both are important as KEK's contribution to society, which will also help improve KEK's visibility in society.

### 3.2 Particle, Nuclear, and Astrophysics Simulation Program

Numerical simulations using computers — in particular, precise calculations on large-scale computers through lattice QCD simulations — have been indispensable for understanding the results of such experiments as the SuperKEKB/Belle II and J-PARC Hadron. Studies in this field will continue by using the computational resources of the Fugaku supercomputer and the high-performance computing infrastructure (HPCI). The computational resources in KEK will also be supported to provide an entrance to larger computing facilities for the research community in this field.

### 3.3 U.S.–Japan Science and Technology Cooperation Program

This program will continue to be a particularly important international cooperation program owing to its expectation of significant contributions to the development of high-energy physics and related fields.

### 3.4 Research Cooperation Programs/Projects with Foreign Countries

International cooperation programs/projects, such as the Japan–France Toshiko Yuasa Laboratory (TYL) program, the contribution to the Long-Baseline Neutrino Facility (LBNF), and research cooperation with Asia and Oceania regions, including accelerator cooperation with India, will be continued by formulating a budget plan.

### 3.5 TIA Program

The program will continue as a mechanism that enables the accelerator and detector technologies developed by KEK to be useful for society.

### 3.6 Multi-national Partnership Laboratory Program and Multi-corporation

**Partnership Laboratory Program**

These programs will continue because of their function in promoting international collaboration and research cooperation with private industries.

## 4. Research Projects Funded by Function Enhancement Program of MEXT

MEXT has provided funding to research institutions to strengthen their functions for five years since 2017. KEK has used this funding to implement the following programs and the iCASA mentioned in Section 3.1. Because this budget will be continued for research institutions to realize their mission in the coming six years, the following programs will be continued within this program.

### 4.1 Center for Integrative Quantum Beam Science (CIQuS)

Based on the achievements of the past two years, CIQuS will investigate the structure and function of materials through surface, bulk, and heterogeneous structure observations using four types of quantum beam: synchrotron radiation, neutrons, muons, and slow positrons. It will continue to address social issues, such as carbon neutrality. Simultaneously, CIQuS will develop new interdisciplinary research fields with quantum beams by guiding and supporting users for multiprobe applications.

### 4.2 International Accelerator Science Human Resource Development Program

The Inter-Institution Network for Accelerator Science (IINAS) program and the Accelerator Science Human Resource Development Program will be integrated into a new program, IINAS-NX, which aims to foster the next generation of scientists and engineers in accelerator science and related fields.

### 4.3 Detector Technology Development

This project was established in line with the needs of research communities as a platform to promote the development of advanced particle detectors. This activity will facilitate the effective use of the newly built test beamline.

### 4.4 Development of Interdisciplinary Research between Humanities and Sciences

Interdisciplinary research around accelerator facilities is a growing area worldwide. Based on the achievements of the past three years, the foundation of borderless research between humanities and sciences will be established by the collaboration of natural science researchers, who are experts in quantum beams produced by advanced accelerators, and humanities researchers, who are experts in history, archaeology,

culture, and sociology.

**5. Research and Development for International Linear Collider (ILC)**

The International Linear Collider (ILC) program is an accelerator project that explores new physics by studying Higgs bosons in detail. Japanese physics community proposed that the Japanese government host an international project in Japan in 2012. The International Development Team (IDT), established under the International Committee for Future Accelerators (ICFA), proposed launching a preparatory laboratory (pre-lab) prior to the establishment of a new research institute to construct the ILC in its report in June 2021. MEXT set up an ILC advisory panel to study the proposal and the progress of the ILC project in the past three years. In a report published in February 2022, the Panel concluded that establishing a pre-lab was still premature, and it proposed to start the technology development program with the international physics community. It also suggested that efforts should be made to create an environment in which discussions at the government level can be started.

Based on these proposals, KEK is preparing to reach out to research institutes in related countries to launch international technology development collaborations. The R&D currently being carried out at KEK's ATF and STF facilities will be implemented as an international joint project within this framework. KEK will request a new budget to MEXT for this purpose.

**6. Support for International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles (QUP)**

The QUP, proposed by KEK, was adopted for the World Premier International Research Center Initiative (WPI) of MEXT, and the project was launched in December 2021. This program aims to make new measurements possible that could not be performed before by evolving technologies of quantum field measurement, and it is in good agreement with the direction of basic science that KEK is aiming for. In the future, KEK will strengthen support with the aim of maximizing the results of QUP and creating synergies with research in other fields of KEK.

**7. Research Projects to Be Conducted by Institutes and Laboratories of KEK**

Each research program mentioned above was carried out with financial support from MEXT in various support programs. In addition, many relatively small-scale research projects have been conducted with support from research institutes and laboratories at

KEK. These projects are also made at the discretion of each institute and laboratory; however, great care should be taken to balance the research program of the entire KEK with regard to the allocation of human resources. These include the following programs.

-Neutrino–nucleus interaction measurement
-Sterile neutrino search
-Liquid argon detector
-Neutron EDM search — TUCAN experiment at TRIUMF
-ILC physics and detector
-X-band accelerator
-High-efficiency klystrons
-Laser plasma acceleration and dielectric acceleration
-Infrared free-electron laser
-Multifunctional radiation detector for radiation control of high-energy and intense accelerator
-Improvement for efficient and accurate radiation transport codes
-Development of high-field superconducting magnet for future accelerators

**8. Projects to Be Prioritized for New Budget Requests**

One of the objectives of formulating KEK-PIP2022 is to establish a program for new research projects to be implemented at KEK over the next 6 years. At the beginning of this process, the research institutes and laboratories of KEK submitted 13 proposals as research projects that required a new budget. KEK then requested that the Science Advisory Committee of KEK recommend fewer projects out of nine projects that KEK had selected prior to the Committee discussion. Considering the advice of the Committee, KEK finally decided to proceed with five research projects in the following two categories as KEK's priority plan. The criteria for choosing a priority plan are as follows. (i) The proposed project must have scientific importance and international competitiveness. (ii) The program must be appropriate to achieve the goal, (iii) The program can be recommended as a role that KEK should play in the global scientific community centered on accelerator-based science. (iv) The financial feasibility of the proposed project does not need to be considered a prioritization criterion by the Committee.

**Category I: A Project to Be Implemented by KEK without Specifying the Rank**

**● R&D for New Light Source Facility**

This proposal is to promote a multibeam light source facility that combines a low-emittance SR light source and an ultrashort-pulse LINAC-based light source as R&D for KEK's next light source facility. Based on the superconducting linear accelerator and storage-ring accelerator technologies developed and fostered at KEK, KEK has the capability to build a world-leading light source facility with the characteristics of both light sources and make this research infrastructure the global center of photon science. The remarkable scientific potential of such a light source from both national and international user community perspectives will be enormous. It is not just for existing user communities, but for those yet to be established once true scientific capabilities are realized. The application of femtosecond time-resolved studies of materials would be a significant justification for many users.

This R&D should be conducted as a high-priority program at KEK. Technology development and preparation for construction will be carried out in the six years of this PIP, and it is expected that actual construction will be realized in the next PIP period.

**Category II: Projects to make new budget requests according to priority**

Of the new research programs proposed in the process of formulating KEK-PIP2022, the following four are given high priority, and appropriate efforts will be made to receive new budgetary measures in this order.

**II-1. Extension of the J-PARC Hadron Experimental Facility**

In the J-PARC hadron experimental facility, various elementary particle and nuclear experiments are being conducted using kaons and muons obtained from high-intensity protons. The proposed program aims to greatly extend the diversity of research by expanding the hadron experimental facility to increase the energy range, intensity, and momentum resolution of the secondary beams. This project has high scientific significance and international competitiveness in a wide range of sciences, from nuclear and particle physics to cosmology, with unique beamlines and apparatuses. Timely realization of the project will benefit both the international research community and KEK by extending its capability and efficiency in the high-intensity frontier. Because considerable in-kind and personnel contributions in the construction phase are expected from universities and institutes, synchronized cooperation with them will be required to minimize the shutdown period.

**II-2. Strengthening the Cooperation with CERN in Projects Including HL-LHC**

This proposal is to make a larger contribution to the High-Luminosity Large Hadron Collider (HL-LHC) accelerator project. The HL-LHC accelerator aims to increase luminosity by a factor of 10 beyond the LHC's design value to increase the potential for discoveries markedly after 2027. The HL-LHC has been the top-priority project for particle physics worldwide. Recognizing the importance of the LHC as a unique energy-frontier machine, Japanese scientists have played a significant role in the construction of the LHC and in the construction, operation, and data analysis of the ATLAS experiment. For the HL-LHC, Japanese team is playing a key role in the upgrade of the ATLAS detector and is committed to producing the D1 superconducting separation dipoles. Japan will play another key role in the HL-LHC accelerator upgrade with the proposed additional contributions.

**II-3. LiteBIRD**

LiteBIRD is one of the two most powerful CMB B-mode observatories planned in the late 2020s and is unique in that it is the only planned CMB satellite. Although this is different from the research to date at KEK based on experiments using accelerators, this project is highly supported by the relevant communities owing to its affinity in science and technology. It has the potential to make a significant scientific breakthrough in the detection of primordial gravitational waves. Furthermore, the project is well in line with the scope of the newly founded QUP institute.

**II-4. Transmission Muon Microscope**

The world's first transmission muon microscope will be realized by combining the development of ultraslow muon beams and muon acceleration technologies, with which KEK has been leading the world at the J-PARC muon facility. This will achieve a much better spatial resolution for transmission imaging than the existing transmission electron microscope, and it will achieve three-dimensional multilayer imaging owing to the muon's transmission power. The unique features of the facility will open up new fields of muon science, such as the imaging of living cells and elucidation of the mechanism of hydride superconductivity under high pressure. This project has strong synergy with other ongoing projects, such as muon g-2 and EDM.

In addition to the five high-priority projects mentioned above, the following four projects were proposed in the process of formulating this KEK-PIP2020. It is unlikely that KEK will offer funding for these in the next 6 years, so the proposers are encouraged to discuss how to proceed in the future with related research institutes and laboratories.

- Intensity upgrade of the Slow Positron Facility
- KISS II
- Expansion of the Structural Biology Research Center
- Expansion of applied research using superconducting accelerators.

**9. Remarks on Joint Research Programs with Other Institutes**

In addition to the five projects discussed in Section 8, KEK will examine the feasibilities of the new research programs jointly considered with the other research institutes. One is the MLF's second target project, which is the expansion of the J-PARC neutron facility. It is appropriate to continue discussions with the Japan Atomic Energy Agency (JAEA) and MLF stakeholders to prepare for the realization of the project in the six years of this PIP.

The Kamioka Gravitational Wave Detector (KAGRA), which KEK is cohosting with Institute for Cosmic Ray Research, University of Tokyo, and the National Astronomical Observatory of Japan, is considering a large-scale upgrade for the 6th International Gravitational Wave Observation (O6), which is planned for around 2028–2029. The budget request for this project has not yet been decided upon, but if several organizations involved in the project collaborate to request the budget, KEK may request the budget for its share during the next PIP period.

KISS-II is an extension of the KEK-initiative heavy-ion physics project under the MoU with RIKEN, utilizing the heavy-ion accelerators at RIBF. It is encouraged to continue the discussion with RIKEN on how to keep the leadership in promoting the low energy nuclear physics over the whole of nuclear chart.

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