REPORT:

THE THIRD MEETING OF THE KEK SCIENCE ADVISORY COMMITTEE

April 5, 2022

1. Executive Summary

The KEK Science Advisory Committee's third meeting took place virtually on March 7, 8, and 11, 2022. The agenda of the meeting can be found in Appendix A. The membership of the SAC and the charge to the SAC are provided in Appendices B and C, respectively. The presentations were recorded and provided to the SAC prior to the meeting. The SAC was asked to focus on (1) the development of the on-going research programs described in Sections 2, 4, and 6 of the Draft KEK-PIP2022; and (2) the KEK plan on the ILC as a plan to work with the international HEP community described in Section 5 of the Draft KEK-PIP2022. In addition, the SAC was asked to select four projects out of nine new research programs described in the Draft KEK-PIP2022. The SAC appreciates the KEK team's implementation of its April 2021 SAC recommendations.

KEK enables unique scientific opportunities for researchers from academia and industry in Japan and abroad, covering accelerator science, particle physics, nuclear physics, cosmology, material science, and life science. KEK operates and develops world-leading electron-based and proton-based accelerator facilities at Tsukuba Campus and Tokai Campus, respectively. Using various types of beams from these facilities, KEK pursues fundamental laws of nature and the origin of function of materials. KEK develops the next generation of accelerator technologies for a wide range of sciences and it collaborates with industry on research aimed at developing useful products for society. KEK strengthens its portfolio by partnering in activities at other world leading research laboratories and facilities, including LHC/ATLAS experiment at CERN, KISS at RIKEN, UCN at TRIUMF, KAGRA at the Kamioka mine and LiteBIRD in space.

Highlights since the 2021 SAC meeting include releasing the KEK Roadmap 2021 on May 31, 2021, producing the KEK Project Implementation Plan (PIP) to carry out research projects described in the KEK Roadmap with funding resources and priorities, and establishment of a new World Premier Initiative (WPI) research center in December 2021. There have also been changes in the organization. (i) The QUP was established, (ii) The Detector Technology Project Office was closed and the "Detector Technology Development Center" in IPNS was created. The new testbeam line at PF-AR will be handled by the new center. (iii) CASA in Accelerator Lab will be expanded to iCASA "Innovation Center for Applied Superconducting Accelerators."

Operational and scientific highlights include J-PARC's MR performance (before summer, stable operation at FX:515kW, SX:64kW, followed by a long shutdown for MR power supply upgrade); progress in neutrino experiments to explore the origin of matter in the Universe (T2K ongoing, and start of Hyper-Kamiokande project hosted by University of Tokyo and KEK); physics at the Hadron Experimental Facility (intense K-meson, pion meson and muon beams); new phase at the Hadron Hall (achieving maximum beam intensity of 64.5 kW with stable operation and new COMET beamline almost ready); very high efficiency operation

of RCS/MLF; activities at the Muon Facility MUSE at MLF; achievement of the world highest luminosity by SuperKEKB and first publications of Belle II; 48 beamlines of the Photon Factory that support about 3,000 users covering many different fields including materials and medicine.

Comments and Recommendations

The SAC commends the KEK leadership team to produce the DRAFT KEK Project Implementation Plan (PIP), to establish a new WPI program, QUP, at KEK, and to make major progress in ongoing research programs and projects.

The steady decrease in KEK staffing is an ongoing challenge. The SAC recommends to evaluate all the essential expertise and staffing required for the present and planned programs and projects and to develop a plan to mitigate negative impacts.

The SAC strongly supports KEK's full engagement with JAEA's efforts to secure the second target station at the J-PARC MLF. This could double the number of world-class beamlines, and ensure that J-PARC remains competitive with respect to the SNS in the U.S. and the European Spallation Source in Sweden. As part of this process, KEK and JAEA could (and should) seek investment and deeper scientific engagement from other countries in the Indo-Pacific region, especially from Japan's closest neighbours.

The current sharp increase in the cost of electricity will lead to shorter machine running time and it will make a significant impact on the science output. Although this might be a short-term effect due to the extraordinary situation with the COVID and war, its development must be carefully monitored and some mitigation plans must be developed.

2. Sections 2, 4 and 6 of the Draft KEK-PIP2022

Section 2 of the Draft KEK-PIP2022 concerns research projects authorized and carried out with annually budgeted funds. Projects include 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.

Comments and Recommendations

The power upgrade for the J-PARC main ring has been developing well, reaching above 1 MW and moving toward the target 1.3 MW, which is particularly important for the long-baseline neutrino experiments. Construction of the newly approved HyperK experiment is advancing. The previously recommended project for a photon factory was not realised. Therefore, making plans for a new machine is becoming very urgent, given the age of the current facility.

Extension of the muon beam line, which had been approved as the third priority project in the 2016 recommendation, was approved for the fiscal year 2022 but is not yet funded. Given the potential of this beam line beyond the original purpose for the muon g-2 and EDM experiments, its development must be vigorously pursued. One of the flagship experiments, COMET, is finally becoming operational for the first

phase. Forthcoming results are crucial to determine the next step. Therefore, data taking must proceed with high priority.

Sustainable operation of accelerators is becoming very important for research laboratories. Serious effort must be made to make the operation of KEK as a whole more sustainable. The current sharp increase in the cost of electricity will lead to shorter machine running time and it will make a significant impact on the science output. Although this might be a short-term effect due to the extraordinary situation with the COVID and war, its development must be carefully monitored and some mitigation plans must be developed.

KEK contribution to the HL-LHC at CERN, construction of the D1 magnet, is making good progress where the superconducting expertise of KEK is fully exploited. Given the progress in the HL-LHC and KEK expertise in accelerator science, there is still some room for further contribution beyond the current D1 magnet.

Section 4 of the Draft KEK-PIP2022 concerns research projects funded by MEXT as function enhancement budget. Projects include Center for Integrative Quantum Beam Science (CIQuS), International Accelerator Science Human Resource Development Program, Detector Technology Development, and Development of interdisciplinary researches between humanities and sciences.

Comments and Recommendations

While the SAC supports the idea of trying to integrate KEK's use of synchrotron radiation, neutrons, muons and slow positrons, this will be very difficult when all of these activities are so understaffed. We reiterate what we wrote in last year's SAC report:

"*The IMSS's strategy of encouraging multi-platform research is a most laudable one. While particle physics and astrophysics have very good 1:1 mappings onto the technologies they need, this is not the case in materials science – one often has to use multiple techniques, and one cannot predict at the beginning which methods or instruments will eventually be most useful. On the other side, many instruments are very broad in their application and their construction/operation cannot normally be justified on the basis of one big blockbuster scientific question. If KEK tries to pursue a science agenda, it risks becoming decoupled from its assets. And if it were really to succeed at making its instruments productive, it may appear to lack scientific focus. This is a problem everywhere. Having said this, KEK should encourage its university users (and those in RIKEN, JAEA, NIMS, AIST, industry and so on) to use the other tools in its portfolio, where appropriate*."

The SAC supports KEK's continued involvement in the human-resource development activities, to ensure that the next generation of accelerator scientists and engineers is there for future needs. It is also important that KEK maintain its core expertise in detector technology.

The SAC supports KEK's efforts to engage with researchers in the humanities, on problems in cultural heritage, paleontology and so on. This is a growth area around the world, especially at light and neutron sources. Experience elsewhere is that it takes a very different approach, as much of the research is led out of museums or private collections, which have a very different research culture to that in universities (and

especially that of physics). For instance, there will be very specific "chain of custody" issues, in order to deal with unique and valuable cultural artifacts.

Section 6 of the Draft KEK-PIP2022 concerns support for International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles (QUP).

Comments and Recommendations

The SAC congratulates the KEK team for bringing this new WPI (the World Premier International Research Center Initiative) program to KEK. The QUP (Quantum-field Measurement Systems for Studies of the Universe and Particles) has an exciting program and the SAC looks forward to hearing more about this at the next SAC meeting.

The SAC is pleased to hear that Dr. Masashi Hazumi was appointed as the director of QUP and that QUP missions are development of novel detector systems to achieve major discoveries in particle physics and cosmology; collaboration with research groups around KEK on novel measurement systems to boost KEK's research as a whole; and society-related research with the Toyota group.

This center will conduct interdisciplinary research for developing new methodologies by integrating particle physics, astrophysics, condensed matter physics, measurement science, and systems science. QUP's inventions and development will be based on the most fundamental object of nature, the quantum field. The center chooses to develop a new superconducting sensor system for the LiteBIRD satellite as QUP's flagship project. As for the 2nd flagship project, the center will open-call for new innovative proposals for discovering a new quantum field.

The SAC looks forward to a report on the QUP at the next SAC meeting.

3. Section 5 of the Draft KEK-PIP2022

Section 5 of the Draft KEK-PIP2022 concerns research and development for International Linear Collider.

Comments and Recommendations

The SAC was informed at this meeting that since the Draft KEK-PIP2022 was produced on January 31, 2022, there has been new information concerning the Pre-lab. The Pre-lab proposal was submitted to MEXT by KEK and MEXT formed an ILC Advisory Panel in July 2021. The Panel issued its recommendation on Feb. 14, 2022. The Panel found that it is still premature to proceed into the ILC Pre-lab phase, and recommends the ILC proponents to reexamine a global approach towards a Higgs factory taking into account the progress in the various studies such as the FCC and ILC, while continuing the development work in the key technological issues for the next generation accelerator.

The SAC supports KEK's plans: (i) revisit and reevaluate the path for realizing the ILC as a Higgs factory taking into account the progress in various fronts including the FCC feasibility study; (ii) in collaboration with the International Development Team (IDT), propose a framework to ICFA to address the pressing

accelerator R&D issues for the Pre-lab, where joint development will be done by the participating laboratories on the selected subjects; and (iii) in collaboration with ILC-Japan, establish a new organization that will centrally manage ILC communications activities.

The SAC looks forward to a progress report at the next SAC meeting.

4. Section 8 of the Draft KEK-PIP2022

Section 8 lists nine new research programs proposed by the research institutes of KEK. The SAC is asked to choose four projects out of these, and prioritize them. The criteria for prioritization include (i) Scientific significance and international competitiveness of the proposed project; (ii) Appropriateness of the program to achieve the goal; (iii) Can the program be recommended as a role that KEK should play in the global science community centered on the accelerator based science?; and (iv) Financial feasibility of the proposed project needs not to be considered as criteria of the prioritization at this meeting.

The SAC divides the nine proposed programs into three categories:

- Category I: Recommended programs for MEXT's support without ranking
- Category II: Recommended programs for MEXT's support with ranking
- Category III: Others

Category I

- **R&D for New Synchrotron Light Source Facility**
  The proposed R&D, a hybrid ring with two photon beams, is a highly original and flexible design concept which leverages a unique combination of outstanding expertise from various accelerator branches of KEK: PF, ILC/STF, cERL, iCASA, SuperKEKB. The remarkable scientific potential of such a lightsource from both a national and international user community perspective will be enormous. Not just for existing user communities but for those yet to be established once the true scientific capabilities are realised. The application of simultaneous time-resolved and spatial-scale studies of materials would be a significant justification for many users alone. The PF is the oldest major lightsource still in operation and has been acknowledged as a world leader in synchrotron science. It has been the testing ground for a range of new technologies and has had a significant impact through the mentoring of international communities. Building on decades of KEK innovation this project presents a unique opportunity within the timeline of the present PF transition. Once the feasibility is established, the construction could even be staged, with energy recovery and FEL as possible future additions.

Category II

1. **Extension of the J-PARC Hadron Experimental Facility**
   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 apparatus. We strongly endorse timely realization of the project that will benefit both the international research community and KEK by extending capability and efficiency in the high intensity frontier. Since

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 shut-down period.

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 in order to markedly increase the potential for discoveries after 2027. The HL-LHC has been the top priority project for particle physics world-wide. Recognizing the importance of the LHC as the unique energy-frontier machine, Japan had played a key role in the construction of LHC, and in the construction, operation and data analysis of the ATLAS experiment. For the HL-LHC, Japan is playing a key role in the upgrade of the ATLAS detector and is committed to produce the D1 superconducting separation dipoles. With the proposed program, Japan will play a key role in the upgrade of the HL-LHC accelerator upgrade.

3. **LiteBIRD**
   LiteBIRD is one of the two most powerful CMB B-mode observatories planned in late 2020s and is unique in that it is the only planned CMB satellite. It has the potential to make a significant scientific breakthrough in detecting the primordial gravitational wave. Furthermore, the project is well in line with the scope of the newly founded QUP institute. KEK should seize the chance of making an important scientific discovery by playing a leadership role.

4. **Transmission muon microscope**
   The transmission muon microscope is to combine the cutting-edge technologies of ultra-slow muon beams and muon acceleration. This is the first project of this kind, and KEK has been the world leader with the J-PARC muon facility. This will reach much better spatial resolution for transmission imaging than the existing transmission electron microscope, and achieve three-dimensional multi-layer imaging owing to the muon's transmission power. This new technology will open up new muon science, such as imaging of living cells, visualization of magnetic fields in bulk materials, and elucidation of the mechanism of hydride superconductivity under high pressure. This project has strong synergy with the other on-going projects such as muon g-2 and EDM.

Category III

- **KISS II**
  The KISS II project aims to explore the heavy neutron-rich nuclides leading to uranium, the heaviest naturally occurring element on Earth. The ultimate goal is to quantify with precise spectroscopy the r-process for heavy elements produced in neutron star mergers. The KISS-II at RIKEN is designed to be the first facility with the ability to effectively connect production, separation, and analysis of nuclides around uranium. The project appears not to have technical shortfalls. Because of the timeline of other competing projects in the international scenario there is urgency to start soon the construction of this facility. The project has an excellent cost-benefit ratio and thus efforts should be made to fund it in the best possible way. Since the major cost of the project is the construction of the solenoid magnet, which has similar specifications to the muon

capture solenoid used in a couple of places in JPARC, it will be important to explore possibilities to utilize existing magnets in KISS II, while the project can start without the solenoid to gain the first order-of-magnitude enhancement. ***The SAC recommends KEK search for all funding possibilities in order to keep its leadership in this research area and to reinforce further the collaboration with RIKEN for their mutual benefit.***

- **Expansion of applied research using superconducting accelerators**
  This proposed program is in preparation for two accelerator projects: EUV-FEL lithography based upon ERL-SASE-FEL at KEK's cERL facility with a current of 10 mA and a 10-MeV, and 50-mA accelerator using Nb3Sn thin film cavities. The proposed budget is approximately $1M per project, per year for six years. The main purposes include significantly expanding the applied research using superconducting accelerators and preparations for EUV-FEL light sources for industrial semiconductor lithography and 99Mo production. The proposed projects will make KEK world-leading in the field of ERL and SRF accelerator technology. Having the program funded not only keeps KEK at the cutting edge of the accelerator science and technology frontier but also helps to retain key subject matter experts and resources for future growth to world leadership in accelerator science. ***The SAC recommends to search for all funding possibilities for the program.***

- **Expansion of the Structural Biology Research Center**
  The SBRC is a successful research center, where protein crystallography, small angle X-ray scattering (SAXS), and cryo-electron microscopy (cryo-EM), together with a fully automated crystallography facility, make possible to go from diffraction data collection, to structure solution, and structure refinement. It plays an important role in structural biology in Japan. The proposal aims at extending the center with another Cryo-EM (300kV) and a cryo-tomography (cryo-ET) instrument. Furthermore, it aims at expanding the data management capability through the "Go to cloud" project. The SBRC should be supported, as it plays an important role in the Japanese Structural Biology community, and its development goes in the direction of similar initiatives all around the world, combining multidimensional probe instruments for tackling the structural biology problems with complementary techniques. ***The SAC recommends to continue searching for other external sources, as for example the BINDS project, in order to develop the SBRC vision.***

- **Intensity upgrade of the Slow Positron Facility**
  The project, aiming at making SPF the most intense pulsed positron beam facility in the world, has interdisciplinary interest, since it combines technological developments with upgrades of existing facilities in view of offering state-of-the-art instrumentation to the existing surface science community. The development of the positron source could be of interest for other projects, such as SuperKEKB and ILC. The SAC considers that the project needs further definition. A 1-GeV LINAC and the positron source able to stand the proposed high power are demanding infrastructures in terms of resources. In particular the foreseen cost for the LINAC seems quite optimistic. ***The SAC recommends reviewing the resources-schedule-cost of the whole project and developing the science-case, highlighting complementarities and advantages with respect to X-ray instruments for surface science, in particular considering the proposed new light source facility.***

Appendix A: Agenda of the Third Science Advisory Committee

Day 1 Monday, March 7, 2022

---- Open session ----

20:00 - 20:05 (5) Introduction / charge to the committee (M. Yamauchi, KEK D.G.)

20:05 - 20:20 (15) Research overview / follow up on the previous meeting report (Y. Okada, Executive director)

20:20 - 20:35 (15) Introduction of KEK PIP (except for “Article 8”) (M. Yamauchi, KEK D.G.)

---- Projects to be prioritized (each talk is presentation 10 min. + discussion 20 min.) -----

20:35 - 21:05 (30) Extension of the J-PARC Hadron Experimental Facility (F. Sakuma, Riken)

21:05 - 21:10 (5) Break

21:10 - 21:40 (30) Strengthening the cooperation with CERN in projects including HL-LHC (K. Hanagaki, IPNS)

21:40 - 22:10 (30) Transmission muon microscope (K. Shimomura, IMSS)

22:10 - 22:40 (30) New Synchrotron Light Source Facility (N. Funamori, IMSS)

22:40 - 23:00 (20) Executive session

Day 2 Tuesday, March 8, 2022

20:00 - 20:30 (30) LiteBIRD (M. Hazumi, IPNS)

20:30 - 21:00 (30) Intensity upgrade of the Slow Positron Facility (K. Wada, IMSS)

21:00 - 21:30 (30) KISS II (M. Wada, IPNS)

21:30 - 21:40 (10) Break

21:40 - 22:10 (30) Expansion of the Structural Biology Research Center (T. Senda, IMSS)

22:10 - 22:40 (30) Expansion of applied research using superconducting accelerators (H. Sakai, ACL)

22:40 - 23:00 (20) Executive session

Day 3 Friday, March 11, 2022

---- Closed session ----

20:00 - 23:00 (180) Discussion (Closed session)

Appendix B: Members of the Science Advisory Committee

Field	Name	Affiliation
HEP	Young-Kee Kim (chair)	University of Chicago
	Jun Cao	Institute of High Energy Physics, Chinese Academy of Science
	Tatsuya Nakada	EPFL, Ecole polytechnique fédérale de Lausanne
Theory	Tao Han	University of Pittsburgh
Nuclear	Takashi Nakano	Osaka University
	Angela Bracco	INFN, Istituto Nazionale di Fisica Nucleare
Accelerator	Frank Zimmermann	CERN, European Organization for Nuclear Research
	Jie Wei	Michigan State University
PF (Synchrotron Radiation)	Caterina Biscari	ALBA Synchrotron
	Robert Norman Lamb	CLS, Canadian Light Source
Neutron	Robert Alan Robinson	University of Wollongong, Australia (retired, ex ANSTO)
	Sung-Min Choi (unable to attend this time)	KAIST, Korea Advanced Institute of Science and Technology
Muon	Elvezio Morenzoni (unable to attend this time)	PSI, Paul Scherrer Institute

Appendix C: Charge to the Science Advisory Committee

Sections 2, 4 and 6 of the Draft KEK-PIP2022 describe KEK's plan to develop its on-going research program. The outline of these programs has been approved by MEXT, and therefore, there is no room for major changes in these. We will be grateful, of course, if you give us your advice on the development of these programs.

Section 5 describes our plan toward the ILC in line with the recent recommendations by the ILC Advisory Panel of MEXT. We would appreciate, if you give suggestions to make this plan more appropriate as a plan for KEK to work with the international HEP community.

Section 8 lists nine new research programs proposed by the research institutes of KEK. Please choose four projects out of these, and prioritize them. We will work with MEXT to find appropriate methods to obtain a new budget to proceed with the selected ones, according to the priority you give. The criteria for prioritization are

- Scientific significance and international competitiveness of the proposed project
- Appropriateness of the program to achieve the goal
- Can the program be recommended as a role that KEK should play in the global science community centered on the accelerator-based science?
- Financial feasibility of the proposed project needs not to be considered as criteria of the prioritization at this meeting.