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Update of the Japanese Strategy for Particle Physics

Japan High Energy Physics Committee[1]:

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Preface:

In September 2017, the Japan Association of High Energy Physicists (JAHEP) updated the Japanese strategy for future particle physics by endorsing the recommendations of the Committee on Future Projects in High Energy Physics. Since then there have been important developments in the field that include the formation of the ILC International Development Team to prepare the ILC Pre-Lab in Japan, gradual implementation of the HL-LHC project in MEXT's Large Scientific Research Projects in Japan, the official approval and start of construction of the Hyper-Kamiokande, the beginning of the Belle Ⅱ physics program at the newly operating SuperKEKB, and the recent update of the European Strategy for Particle Physics. Here we briefly summarize all these recent developments. More detailed accounts will be reported in our submissions to the Snowmass 2021 Proceedings.

[1] Representing the Japan Association of High Energy Physicists (JAHEP)

1 The Japanese Strategy for Particle Physics 2017

In September 2017, the Committe on Future Projects made the following recommendations to update the Japanese Strategy,[1] following the JAHEP's proposal of early realization of the ILC as a Higgs factory[2,3]:

> In 2012, not only was a Higgs boson with a mass of 125 GeV discovered at the LHC, but three-generation neutrino mixing was also established. Taking full advantage of the opportunities provided by these discoveries the committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.
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> - With the discovery of the 125 GeV Higgs boson at the LHC, **construction of the International Linear Collider (ILC) with a collision energy of 250 GeV should start in Japan immediately** without delay so as to guide the pursuit of particle physics beyond the Standard Model through detailed research of the Higgs particle. In parallel, continuing studies of new physics should be pursued using the LHC and its upgrades.
> - Three-generation neutrino mixing has been established and has provided a path to study CP symmetry in the lepton sector. Therefore, **Japan should promote the early realization of Hyper-Kamiokande as an international project** due to its superior proton decay sensitivity, and should continue to search for CP violation with the T2K experiment and upgrades of the J-PARC neutrino beam.
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> The High Energy Committee should pursue all available options to achieve the early realization of these key, large-scale projects.
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> It is important to complete construction of SuperKEKB and start physics studies as scheduled. Some of the medium- and small-scale projects currently under consideration have implicit potential to develop into important research fields in the future, as happened with neutrino physics. They should be promoted in parallel in order to pursue new physics from various directions. Flavor physics experiments, such as muon experiments at J-PARC, searches for dark matter and neutrinoless double beta decay, observations of CMB B-mode polarization and dark energy, are considered to be projects that have such potential.
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> Furthermore, accelerator R&D should be continued to dramatically increase particle collision energies in preparation for future experimental efforts that may indicate the existence of new particles and new phenomena at higher energy scale.

2 Recent Developments in Implementing the Strategy

The international consensus for an electron-positron Higgs factory as the highest-priority next collider has helped further strengthen efforts to realize the ILC in Japan during the past year. An increasing number of people from various sectors, including scientists, politicians, industry members, business circles, and local communities, are proactively working together towards the realization of the ILC. The recent progress and developments in various sectors of Japan were summarized in a document[4] that was sent to the European Strategy Group in December, 2019.

This August ICFA announced the formation of the ILC International Development Team[5] as the first step towards the preparatory phase of the ILC project, with a mandate to prepare the ILC Pre-Lab in Japan by the end of 2021. The Team has replaced the LCB/LCC organization that had ended its mandate at the end of June, 2020. KEK now hosts the Team and provides necessary support.

A large part of the Japanese community are working at the energy frontier and are strongly committed to the LHC and its upgrade. Japan's participation in the HL-LHC has been officially listed in the MEXT roadmap under the title of "Particle Physics with the HL-LHC" since 2017 and the budget for the HL-LHC has been allocated since 2019. Taking advantage of Japan's expertise in the current LHC program, Japan's contributions to the HL-LHC consist of the R&D and construction of beam separation dipole magnets, and the inner tracking system and the muon trigger system of the ATLAS experiment.

This year the Hyper-Kamiokande (Hyper-K) project[6] was officially approved by the Japanese government. The construction has already started and the physics program is expected to start in 2027. The Hyper-K is a world-leading international project hosted by Japan aiming to elucidate the origin of matter and the Grand Unified Theories. It consists of the Hyper-K detector, which has 8.4 times larger fiducial mass than the Super-Kamiokande, and a high-intensity neutrino beam produced by the J-PARC accelerator facility that is being upgraded in stages towards 1.3 MW beam power along with the T2K physics program. The Hyper-K collaboration is being formed by interested international groups, currently from 19 countries including the United States that has historically contributed significantly to neutrino programs in Japan. It is anticipated that international contributions will cover additional inner-detector photosensors, sensor covers and light collectors, outer-detector photosensors, readout electronics and data acquisition system, water system upgrade, detector calibration systems, downstream offline computing systems, and the near and intermediate detector complex.

After the completion of construction and commissioning with collidng beams in 2018, the physics program of the SuperKEKB/Belle II started in the spring of 2019. The SuperKEKB has already achieved the world's highest instantaneous luminosity of 2.40×10^{34} cm^{-2}s^{-1} by using the "nano-beam" technology, and the Belle II continues to take data with tolerable background level. Major milestones of reaching peak and integrated luminosities of $\mathcal{L}_{\rm peak} \sim 1 \times 10^{35}$ cm^{-2}s^{-1} and $\mathcal{L}_{\rm int} \sim 5$ ab^{-1} are expected within the next few years, and that will bring significant physics results with a large sample of heavy falvor particle decays. It is the aim of the project to achieve $\mathcal{L}_{\rm peak} \sim 6 \times 10^{35}$ cm^{-2}s^{-1} and accumulate $\mathcal{L}_{\rm int} \sim 50$ ab^{-1} by as early as 2030, by upgrading machine and detector components, such as the interaction region, superconducting final focus, as well as detector susbsystems. Feasibility studies are in progress for much higher luminosity beyond 50 ab^{-1} and for electron beam polarization as possible future upgrades.

Kaon and muon experiments at the J-PARC provide opportunities to search for new physics through rare processes and precision measurements. The KOTO is a unique ongoing experiment that aims to measure the $K_L \to \pi^0 \nu \bar{\nu}$ process, and the COMET Phase-I experiment is under construction to search for muon-electron conversion with sensitivity better than 10^{-14}. Outside Japan the MEG II experiment starts looking for flavor-violating muon decays at the PSI.

Accelerator R&D aiming for higher energy collisions is crucial for future high energy physics. There have been continued efforts on developments of superconducting magnets, higher gradient accelerating structure, muon collider, and novel accelerator technologies such as laser-plasma accelerator. Among others, the Japanese community intends to contribute to R&D for superconducting magnets as preparations for a next-generation hadron collider beyond the LHC and superconducting RF technologies which could be used for future upgrades of the ILC.

The Japanese community hopes to continue to work together with international colleagues to achieve global scientific goals of particle physics.

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