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Japan Association of High Energy Physicists

Scientific Significance of ILC and Proposal of its Early Realization in light of the Outcomes of LHC Run 2

The International Linear Collider (ILC) is a linear electron-positron collider, a key experimental facility that enables forefront research at the energy frontier in high energy physics. The ILC has been developed through an international collaboration overseen by the International Committee for Future Accelerators (ICFA). The international team of physicists, Global Design Effort, published in 2013 the Technical Design Report of a 200-500 GeV (extendable to 1TeV) center-of-mass collider. In October 2012, the Japan Association of High Energy Physicists (JAHEP) proposed to construct ILC in Japan under a global collaboration with consensus of the international community and active participation from each country. This proposal received many positive responses from the international community. In particular, it garnered support from European countries and the United States, who were also developing their future particle physics projects, as well as from the ICFA. Upon the launch of JAHEP's proposal, the Science Council of Japan and a panel of experts under the Ministry of Education, Culture, Sports, Science and Technology discussed the proposal. They noted that the large expense and cost sharing are issues that must be solved. Subsequently, a research and development project was initiated to reduce the costs associated with ILC based on the discussions between the governments of Japan and United States. Meanwhile, the Large Hadron Collider (LHC) Run 2 experiments at CERN have continued to progress, and new results have been published. In this context, JAHEP has deliberated the scientific significance of ILC and has come to a conclusion; JAHEP proposes to construct a 250 GeV center-of-mass ILC promptly as a Higgs factory.

The driving force for JAHEP's proposal released in October 2012 is that particle physics entered a new phase following the discovery of a Higgs boson. Research in the 20th century particle physics focused on elucidating fundamental forces, save gravity, of nature: strong, weak and electromagnetic forces. The existence of a Higgs boson was predicted by the Standard Model, which successfully describes these three forces in a unified way. A Higgs boson was discovered as predicted, indicating that our understanding of these three forces has greatly advanced. On the other hand, the real nature of the Higgs boson remains unknown. Candidate theories to explain the origin of Higgs bosons include new forces, new hierarchies of matter, and extension of the space-time structure. In this light, studying the Higgs boson is definitively important to determine the future of elementary particle physics. The ILC, with additional advantage of energy-extendable and beam-polarization capabilities due to being a linear accelerator, would be the best suited facility for this purpose.

The LHC experiments have an excellent ability to explore new physics by observing new strongly-interacting particles and their decays. The LHC Run 2 experiment, where the center-of-mass energy was increased from 8 TeV to 13 TeV, began in 2015 and the accelerator operated smoothly throughout 2016. The exploratory area (or mass scale) of the Run 2 has, indeed, significantly expanded compared to that under 8-TeV-energy operations. The results reported in 2016 showed that new particles anticipated by physics beyond the Standard Model are unlikely to exist below the mass scale of 1 TeV. This important finding at LHC underscores that the most imminent and important goal of ILC is to explore new physics by precision measurements of the Higgs boson and search for a class of new particles that ILC could directly produce but LHC has difficulty to observe.

JAHEP has established the "Committee on the Physics Significance of ILC 250 GeV Higgs Factory." The charge to this committee is to verify the significance of a 250 GeV center-of-mass energy ILC ("ILC250"), in particular, by comparing with the case for a 500 GeV center-of-mass ILC ("ILC500") and the case for no ILC at all. The roles that ILC250 should play were examined from the following perspectives: determination of the energy scale of new physics by precision measurement of the Higgs boson and thorough examination of the Standard Model, elucidation of electroweak symmetry breaking and the origin of matter and antimatter asymmetry, and searching for particles that are candidates of the dark matter. In the Committee's deliberation, possible synergies with the High-Luminosity LHC (HL-LHC) and SuperKEKB /Belle II were taken into account.

The Committee's conclusions are summarized as follows:

- ILC250 should run concurrently with HL-LHC to enhance physics outcomes from LHC.
- Given that a new physics scale is yet to be found, ILC250 is expected to deliver physics outcomes that are nearly comparable to those previously estimated for ILC500 in precise examinations of the Higgs boson and the Standard Model.
- The ILC250 Higgs factory, together with HL-LHC and SuperKEKB, will play an indispensable role in the discovery of new phenomena originating from new physics with the energy scale up to 2–3 TeV and the elucidation of the origin of matter-antimatter asymmetry.
- A linear collider has a definite advantage for energy-upgrade capability. ILC250 possesses a good potential for its upgrades to reach the higher energy of new physics that the findings of ILC250 might indicate.

As discussed above, the scientific significance and importance of ILC has been further clarified considering the current LHC outcomes. ILC250 should play an essential role in precision measurement of the Higgs boson and, with HL-LHC and SuperKEKB, in determining the future path of new physics. Based on ILC250's outcomes, a future plan of energy upgrade will be determined so that the facility can provide the optimum experimental environment by considering requirements in particle physics and by taking advantage of the advancement of accelerator technologies. It is expected that ILC will lead particle physics well into the 21st century.

To conclude, in light of the recent outcomes of LHC Run 2, JAHEP proposes to promptly construct ILC as a Higgs factory with the center-of-mass energy of 250 GeV in Japan.