Summary of the International Linear Collider (ILC) Advisory Panel's Discussions to Date

June 25, 2015
International Linear Collider (ILC) Advisory Panel

Contents

1. Discussion background and target

(1) Discussion background

The International Linear Collider (ILC) is an elementary particle physics project investigating electron and positron collisions at high energy using a linear collider about 30km long. The project is expected to help untangle the riddle of the birth of the Universe by boosting elementary particle physics to its next stage based on detailed clarification of "Higgs boson", which is considered to be the origin of the mass of matter, and possible discoveries of new particles beyond the Standard Model of elementary particle physics.

The ILC project has been promoted by the international community of elementary particle physicists as a global project. An overview of the technical design of the facility was given in the Technical Design Report (TDR) in June 2013. The international community of the ILC project proposes to construct an ILC in Japan. In addition, there are growing moves in Japan to launch the project in Japan in expectation of creating an international science city accompanying the construction of the ILC.

Based on this background, MEXT has decided to study further the ILC project.

(2) Discussions at MEXT in response to remarks by the Science Council of Japan (in September 2013)

In May 2013, MEXT commissioned the Science Council of Japan (SCJ) to hold deliberations on the scientific significance and issues related to the ILC project. The SCJ subsequently summarized their responses in "Remarks on the International Linear Collider Project" (September 30, 2013, SCJ)), stating, "We recognize the scientific merit of the project in elementary particle physics. However,…in light of the huge investment necessary for the project, a clearer and more convincing explanation for the ILC project, including the relation with the LHC, is desirable." It added, "It is too early to approve the project at the present time…We recommend to the government to approve funding for further necessary investigations to evaluate whether to go ahead with the ILC project and to proceed with intensive investigations and discussions for two or three years, including experts in other fields and relevant government agencies".

Based on this recommendation, MEXT set up an advisory panel for the ILC project under an internal task force in May 2014. This advisory panel is tasked with investigating relevant issues of the ILC project.

It was decided at the 1st advisory panel meeting in May 2014 to set up two working groups (Elementary particle physics and nuclear physics working group and the TDR-validation working group). These working groups discussed the scientific merits of the project justifying the large investment in it, and considered the cost and technical issues described in the TDR. The former working group had eight meetings and the latter had six meetings by March 2015, finally compiling reports on their findings.

Furthermore, MEXT commissioned the following survey in JFY 2014: "Survey of spin-off effects of the ILC project from technical and economic aspects and research trends in elementary particle physics and nuclear physics including necessary technologies in the world". (Commissioned Nomura Research Institute Co., Ltd.).

At the third advisory panel meeting held in April 2015, reports were given on the investigations by the two working groups and on the commissioned survey of spin-off effects of the ILC project from technical and economic aspects.

(3) Rationale for this Discussion Summary

Based on the background described above, in this report the advisory panel summarizes discussions made after the reports from the two working groups and on the survey of the spin-off effects of the ILC project.

In this report the advisory panel intends also to clarify issues to be discussed in the future (See supporting document).

2. Overview of discussions

(1) Scientific merit of the ILC project

The discovery of Higgs boson has completed the Standard Model components although there are still many things that cannot be explained in the Standard Model. Elementary particle physics aims at exploring the physics beyond the Standard Model from now on.

The ultimate goal of elementary particle physics is to gain a consistent understanding of the Universe and elementary particles. For this purpose it is important to study experimentally the unification of forces, supersymmetry and other new physics. Different approaches to address these questions are being taken around the world.

The ILC[1] is considered to be important because of its capability to investigate new physics beyond the Standard Model by exploring new particles and precisely measuring the Higgs boson and top quark. It should be also noted that the ILC might be able to discover a new particles which are difficult to be detected in LHC experiments.

ILC experiments are able to search for new particles, different from the ones that LHC experiments have been searching for. In case these new particles are supersymmetric particles, ILC and LHC experiments can study them complementally. On the other hand ILC experiments can carry out more precise measurement of the Higgs boson and the top quark, which are beyond the reach of LHC experiments.

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[1] In the elementary particle physics and nuclear physics working group, and the TDR-validation working group, "ILC" means a "500 GeV ILC" as described in TDR and is treated in the same way in this report. Electron Volt (eV) is a unit of energy. 1 eV corresponds to energy obtained by an electron accelerated in 1-Volt electric field. $1\text{eV} = 1.6\times10^{-19}\text{J}$

In the current LHC plan, experiments at 13TeV will continue until the end of 2017, and then another run period is scheduled until 2022 after a few years' interruption. In the period between 2025 and 2035 further high-statistics experiments are anticipated after upgrading the accelerator and detectors. If any new particle(s) are within the reach of LHC experiments, discovery of such particles are highly anticipated in the current 13TeV operation period.

There are two possible predictions of ILC achievements depending on the results obtained in the LHC experiments. If LHC experiments find any new particle(s) whose mass is below a certain energy, it will be possible for ILC experiments to study the new particle(s), in addition to precision measurements of the Higgs boson and the top quark.

Second, if no new particle is found in the 13TeV operation of LHC or the mass of the discovered particle is above a certain energy, then the main subject to be studied in ILC experiments will be the indirect exploration of new physics through precision measurements of the Higgs boson. Even though LHC experiments on the Higgs boson and top quark measurements have come first, ILC experiments will have superior capabilities for studying the properties of the Higgs boson and the top quark with precision, providing attractive opportunities for the ILC project.

Thus the specifications of the performance and the scientific achievements of the ILC are considered to be designed based on the results of LHC experiments.

(2) Validation of TDR

Total construction cost has been estimated to be 990.7 Billion JPY for the accelerator construction and 100.5 Billion JPY for the detector. Yearly budget necessary for the machine operation has been estimated to be 49.1 Billion JPY[2] .

In the TDR, contingency costs of about 25% are included but this figure stems only from the ambiguity of the cost estimate. Other kinds of possible cost increases related to technology risk, construction period extension risk, and market risk etc. should also be considered.

It should be noted that the contingency cost is minimized in TDR because the most plausible cost estimate has been taken. This could cause cost increases in case of unexpected failures in construction and/or human resource arrangement.

From a technical point of view, the design is based on actual results of previous studies, leaving only a fractional margin of deviation from them. Attention must be paid to the conducting of performance tests in a large system. The project should also be able to ensure the quality of components produced in different regions of the world.

Based on previous experience with the construction of large-scale facilities, the ILC project should consider possible cost increases due to a limited number of materials suppliers, further cost reduction in mass production, risk management of unexpected accidents in the infrastructure

[2] International tender is considered here supposing 1 Euro=115 JPY and 1 US dollar = 100 JPY.

fabrication such as water inflow to the tunnel from the environment, and preparation of countermeasures not listed in the TDR.

It is necessary to do risk management and prepare countermeasures against possible earthquakes near the site because the project is a long-term one both for construction and operation.

The ILC project utilizes large amounts of acceleration RF cavities. Their components are produced in different regions in the world and are assembled before installation. It is important to ensure the reliability of the assembled equipment. For this purpose, the project should have clear prospects for the quality control of components and reliable assembly within the system.

(3) International collaboration

The ILC project is an international project requiring enormous investment. It is necessary to conduct the project with support not only by a single country but also by international collaboration. The cost should be shared in such kind of international collaboration. It is important to confirm the willingness of each participating country to cover a reasonable part of the project cost.

The project should consider how to secure human resources, salaries for employees, and so on and how to organize the international collaboration.

The European and American particle physics community expects Japan to proceed with the ILC project in line with their strategies. However, current plans and budget of their countries do not explicitly define the ILC project. It is necessary to proceed based on worldwide attitudes to the ILC project.

It should be noted that the ILC project will lose international momentum if decisions on the ILC project implementation are not made in a timely manner.

(4) Social effects of the ILC project

The Survey and Analysis of the Technological and Economic Spin-Offs of the ILC Project and Global Research and Technology Trends in Particle and Nuclear Physics estimates that the ILC project will in the end generate domestic demand worth JPY 2.10 trillion and lead to production worth JPY 4.46 trillion[3].

The analysis also indicates that, in light of past experience, the ILC project may be expected to generate a certain degree of technological spin-offs. It is not clear, however, whether it will be

[3] This is the estimated impact of the ILC project over a 10-year construction period and a 10-year operational period. This estimate excludes expenditures whose preconditions are uncertain (e.g., expenditures on preparatory work, common infrastructure, construction of the main research institute, and consumption by conference participants) and expenditures on regional infrastructure.

possible to put original ILC technologies to normal consumer use and/or use in product development[4].

It is important to obtain the agreement and support of the public and the scientific community when deciding whether to go ahead with the project.

(5) Examples of past large accelerator facilities

The largest amount of funds was spent for construction of the Japan Proton Accelerator Research Complex (J-PARC), which was 150 Billion JPY. Super Photon ring-8GeV (Spring-8) spent 110 Billion JPY and Electron-Positron Collier Accelerator (KEK-B) spent 37.8 Billion JPY for their construction. In contrast to these construction costs, the ILC project demands more than 1 Trillion JPY for construction; a more precise cost estimate and evaluation of corresponding scientific achievements in relation to the cost should be made.

The largest accelerator in the world is the CERN LHC. Necessary costs for the LHC accelerator are estimated to be 500 Billion JPY. The accelerator was constructed in an existing tunnel, and this estimate does not include employment costs.

A project had been planned in the United States during the same period of LHC, Superconducting Super Collider (SSC). Researchers participating in the SSC pointed out the following as main reasons why the project was terminated. These factors should be considered in a large-scale project such as ILC;

- The US budget policy became austere,
- Necessary costs increased owing to the design change (from US$4.5 billion to US$11.0 billion,
- Spin-off effects were overblown and induced negative reactions, and
- Site selection (construction in a completely vacant green field) triggered various problems later.

3. Recommendations

Based on the investigations and reports by the working groups and discussions by the advisory panel, the panel recommends the following on the ILC project;

Recommendation 1: The ILC project requires huge investment that is so huge that a single country cannot cover, thus it is indispensable to share the cost internationally. From the viewpoint that the huge investments in new science projects must be weighed based upon the scientific merit of the project, a clear vision on the discovery potential of new particles as well as that of precision measurements of the Higgs boson and the top quark has to be shown so as to bring about novel development that goes beyond the Standard Model of the particle physics.

[4] One example of the unanticipated spin-offs that projects can have is the contribution to the spread of the World Wide Web (www) made by the large-scale particle and nuclear physics experiments at CERN.

The objective of the ILC project is to uncover physics beyond the Standard Model through the precision measurements of the Higgs boson and top quark and through searches for new particles. In case of new discoveries beyond the Standard Model, its scientific impact on elementary particle physics will be significant.

As the ILC project requires huge investment, it is indispensable and essential prerequisite for the implementation to have a clear vision of participation and cost sharing by international partners including European countries and the United States while taking into account mid-term and long-term domestic economic and financial situations.

From the viewpoint the huge investments in new science projects must be weighed based upon the scientific merit of the project, it is necessary to have a clear strategy of the discovery potential of new particles such as supersymmetry particles which are considered as a candidate of the dark matter, in addition to that of precision measurements of the Higgs boson and top quark, has to be shown so as to bring about novel development that goes beyond the Standard Model.

It is appropriate to proceed discussion on a possible international cost sharing scheme of the ILC project by not only taking into account the scheme used by CERN but also taking into account the schemes of existing large scale international projects such as the International Thermonuclear Experimental Reactor (ITER) and International Space Station (ISS).

Recommendation 2: Since the specifications of the performance and the scientific achievements of the ILC are considered to be designed based on the results of LHC experiments, which are planned to be executed through the end of 2017, it is necessary to closely monitor, analyze and examine the development of LHC experiments . Furthermore, it is necessary to clarify how to solve technical issues and how to mitigate cost risk associated with the project.

The specifications of the performance and the scientific achievements of the ILC project depend on the results of LHC experiments in the 13TeV run which is currently going on through the end of 2017. Especially whether new particle(s) can be found or not, and what their mass value(s) would be in case of the discovery, will provide important viewpoint for the judgement.

It is important to show a clear outlook to address technical and cost issues pointed out at the working group discussions.

It is recommended to further enhance the maximum efforts to incorporate technology development that can improve the accelerator performance.

Recommendation 3: While presenting the total project plan, including not only the plan for the accelerator and related facilities but also the plan for other infrastructure as well as efforts pointed out in Recommendations 1 & 2, it is important to have general understanding on the project by the public and science communities.

4. Review of necessary human resources in the construction and operation periods

It is necessary to acquire as many talented human resources as possible, who are capable of integrating the individual components produced in different regions in the world into a system satisfying required specifications. This is because the ILC project intends to integrate large amount of parts produced through international collaboration into a unified system.

In the working group discussions it has been pointed out that ensuring prospects for acquiring human resources is important not only for producing large amount of components and conducting site supervision but also for administrative work to promote international collaboration.

Thus it is appropriate to set up another working group to assess the prospects for acquiring and/or bringing up human resources for construction, operation, and management with a central focus on Japanese human resources.

5. Future prospects of the investigation

We will set up another working group to investigate the issue of necessary human resources and their cultivation.

We will commission another survey using an external research agency in order to understand the world trends in technology issues related to accelerator construction, and in approaches to reduce the production cost of accelerators.

Acknowledgements

We would like to thank all who provided valuable comments concerning the preparation of necessary documents and interviews in preparation of the advisory panel and working group meetings.

Supporting document

Challenges and activities to understand natural laws in a unified framework