ILC, CEPC and Asia View

Wang Yifang 王贻芳
Director, the Institute of High Energy Physics of Chinese Academy of Sciences

The International Linear Collider (ILC) is a machine which can study with impressive precisions the properties of the Higgs boson. Although the Higgs boson was discovered in 2012 by the experiments at the LHC, its couplings and other properties can only be measured at the LHC with an expected precision of about 10%, due to rather high backgrounds from proton-proton collisions. At such a precision, the deviation from the Standard Model,

$$\delta \sim c_i \frac{v^2}{M^2}$$

can only be probed to M ~ 1 TeV, where M is the new physics scale, and δ is the deviation. But from direct searches at the LHC so far, there is no sign for new physics up to this energy scale. To probe new physics to about 10 TeV, it is clear that we need to measure the Higgs coupling to about 1%, which is beyond what the LHC will be able to deliver.

On the other hand, it is known that the Standard Model is not the final theory. There are quite a few defects and shortages. For example, it cannot explain the flavor structure of quarks and leptons, the huge mass differences of quarks, that the vacuum is not stable but meta-stable, the matter-antimatter asymmetry of the Universe, etc. The fact that there is no dark matter particle(s), and that electromagnetic, weak and strong forces are not united at high energies in the Standard Model, are clear indications that we need a more complete and deeper theory. The fine-tuning problem (naturalness) of the Higgs mass, namely the mass of the Higgs is a subtraction of two large numbers at extremely high precision (10^{-34}),

$$m_H^2 = 36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}933{,}023$$
$$-36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}917{,}398$$
$$= (125\ \text{GeV})^2\ !\ ?$$

gives us some indication where the new physics may occur. If there are new physics at the scale of 10 TeV, such a subtraction would be truncated to only a precise of about 10^{-4} level, which is considered “natural” by most. Most theoretical models that extend beyond the Standard Model, including supersymmetry, extra-dimensions, and compositeness, predict that new physics ought to appear at about 10 TeV.

From the above arguments, most people in the community believe that at least one of the next machines beyond the LHC should be an e+e- Higgs factory, which will provide ~1% precision on Higgs couplings for probing physics at 10 TeV. Of course, some people would prefer to have a proton-proton collider to do direct searches up to 10 TeV. However, such a machine needs at least two decades of development time.

It is for this reason that the ILC has enjoyed strong support from the community for more than 20 years. It is technically mature and ready for construction. At a center-of-mass energy of ~250 GeV, most of the Higgs couplings can be measured to about 1% through the process of e+e- → ZH. Furthermore, as a linear collider, it is quite straight-forward to upgrade the ILC to higher energies, say 380 GeV for the top quark and the Htt coupling, and 750 GeV for the triple Higgs coupling. Such a physics program and potential upgrades are so interesting that ILC is well worth the investment.

Since 2012, there are proposals in China(CEPC) and Europe(FCCee) to build a Higgs Factory based on circular e+e- colliders, thanks to the fact that the mass of the Higgs is relatively low. It is understood that for a circumference of ~100 km, the synchrotron radiation is tolerable at 250 GeV, but not much above. Therefore, CEPC is designed to operate at 250 GeV and below with very high luminosities, while ILC is designed to operate at 250 GeV and above, also with quite high luminosities. They have therefore very different upgrade paths: CEPC can go to a high energy pp collider while the ILC can go to higher e+e- energy. Another major difference is the stage of project development: the CEPC just completed the Conceptual Design while the ILC had already completed the Technical Design a long time ago.

In fact, the design of CEPC has benefited a great deal from the work done on the ILC, including physics, machine and detector design, RF technologies, and R&D results of detectors. They are actually complementary with each other in many aspects. For example, ILC has one interaction point with two detectors, which will be used based on the so-called push-pull scheme. Personally I think that the ILC may drop the push-pull option, and choose to have only one detector permanently at the interaction point for a more stable operation, while the needed cross check can be provided by CEPC. In this way, the ILC can have higher performance efficiency. The ILC and CEPC can both benefit for a full coverage of energy range, hence physics, and for more reliable results by cross checks of each other. Indeed the competition and collaboration between the ILC and CEPC will generate a very healthy atmosphere in our community. In summary, we believe that the world may accommodate two frontier e+e- machines for the following reasons: 1) they use very different technologies, both are very useful and important now and towards the future; 2) they have complementary energy coverage; 3) their upgrade paths are different; 4) their systematic uncertainties are different, such as beam energy, bremsstrahlung, etc.; 5) they can provide critical mutual cross checks for major physics results.

The Chinese particle physics community has been always very supportive of the ILC, and has participated in the physics studies, machine and detector R&D, although at a limited scale due to funding. We will certainly participate in the ILC construction and afterwards the physics studies, because we believe that both the ILC and CEPC will help China to become fully engaged with the international field of particle physics. In many ways the future of the CEPC would be improved by the ILC being approved and built. Our intended contribution to the ILC, widely supported by our community but not yet endorsed by our funding agencies, could be at a level of ~5-10%. We also hope that CEPC can be supported by the Japanese community. We believe that a healthy competition and close collaboration is vital for our programs and our field.

The Asia view towards the ILC is also very clear. The ACFA/AsiaHEP, of which China is a member, made a Statement in 2016: “AsiaHEP and ACFA reassert their strong endorsement of the ILC, which is in a mature state of technical development. … In continuation of decades of world-wide coordination, we encourage redoubled international efforts at this critical time to make the ILC a reality in Japan. The past few years have seen growing interest in a large radius circular collider, first focused as a ‘Higgs Factory’, and ultimately for proton-proton collisions at the high energy frontier. We encourage the efforts lead by China in this direction, and look forward to the completion of the technical design in a timely manner”. The ACFA and AsiaHEP reconfirm their support, and member countries will participate in the construction and physics studies if Japan decides to go ahead. The more recent amendment of plans to an initial collision energy of 250GeV for operating as a Higgs factory and with the possibility of energy upgrades in the future, has not

diminished the priority for the ILC in Asia, nor in the world.

It is probably too early and too difficult for me to estimate the Asian contributions. But to my understanding, the ILC will not only propel the particle physics but also will inspire a new generation of young Asians to consider a scientific career as never before. Given the economical scale of Asian countries and their willingness to support science as we can see now, the ILC will be widely supported in the end. The construction of ILC will elevate Asia as a science center of the world, will attract young talent in the region to remain in Asia and world talent to come, and will contribute in a historical way to the development of science in Asia. Together with CEPC, Asia will not only be successful in economy, but also in science.

By the end of the year, input to the European strategy will be completed, and the decision of Japan on ILC is a key that everybody is waiting for. We hope that SCJ will make positive recommendations.