ILD: Proposal for an ILD strategy 2022

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1. Introduction

The ILD experiment has been conceived as an experiment at the proposed ILC. The detector concept has been developed for a science program which spans collision energies from 90 GeV to approximately 1 TeV [1].

ILD as a concept has been developed with a strong focus on particle flow as the central guiding paradigm for event reconstruction, and has been optimized to operate at the full energy span, at center of mass energies up to 1 TeV. With the strong requirement particle flow puts on the reconstruction of individual particles, the detector has been optimized in this direction. This implies an overall excellent granularity of the detector systems, and it implies a system optimized to extract as much information as possible on individual particles. A special emphasis has been put on ensuring a very hermetic detector, down to very small angles relative to the beam line. A special feature of ILD is the use of a large volume time projection chamber as a key component of the central tracker, which allows not only an excellent reconstruction of tracks, but also contributes to a good particle identification by providing ionization information. ILD at the ILC can operate and has been designed to run without a trigger, allowing optimal sensitivity for in particular unexpected signals. The ILD design has been used as a basis of several detector proposals at other colliders.

In recent years, the international community has embraced the concept of a Higgs factory as the most important future direction of the field. This has been clearly formulated in the 2020 European Particle Physics (European Strategy Group) Strategy Update, which has been taken note of by CERN Council in 2020 [2]. Strategy processes in the Americas [3] and in China are still ongoing at the time of writing this document.

However, no final decision has been reached on a particular collider proposal, but rather a number of approaches are followed in parallel, including several linear and circular collider options, with the proposals being at different levels of maturity. In Europe in particular the CERN proposal for a large ring (FCC) which could host initially an electron positron collider, and then be upgraded later to a proton-proton facility, is receiving significant attention [3]. In China, the HEP community proposes the Circular Electron Positron Collider (CEPC), an electron positron Higgs/Z factory, and its tunnel can host a high-energy super proton-proton collider (SPPC) in the future.

The recent report by the MEXT expert panel on the realization of an ILC in Japan suggested that further international planning is required before a concrete decision to host the facility can be made [4]. ICFA has recently extended the mandate of the ILC International Development

Team [6], and discussions with MEXT and international funding bodies are continuing with a view to timely realization of a Japan-hosted ILC, in close cooperation with the political, industrial and research communities.

Considering this situation, the ILD group has initiated a broad discussion process to determine how ILD as a detector concept group should position itself, which options it should support, and how it might interact with more than one collider proposal [7].

2. The ILD group in 2022+: Perspectives

The ILD group sees as its mission the definition and development of a detector concept for high energy electron positron collisions with particle-flow capabilities with optimal particle identification. This mission is not tied to a specific collider proposal. We are interested in a detector which can deliver the science, independent of where this experiment could take place. The ILD group continues to put a large value on energy extensibility, which would allow the execution of a complete program including Z, Higgs and top physics, and maximize the reach of the search for BSM physics. The state of the ILD proposal and a summary of the most recent studies on ILD performance are available in the ILD interim design report, IDR [1].

The origin of ILD is clearly with the ILC concept, and the sets of parameters which have been defined for ILC and for ILD@ILC remain the baseline option for ILD [1] . They form a very well understood set of benchmarks both in detector performance and in science performance. The performance of ILD at other collider options should always be defined relative to this benchmark performance. We remain convinced that the ILC collider option is the most mature proposal, and would offer the fastest possibility to realize a Higgs factory.

Studies to better understand science at the ILC, and to continue the optimization of the ILD detector at the ILC, remain at the core of our mission. The ILD group has been discussing a program of further improvements to the detector, and, in particular, a number of technologically advanced options for ILD, which it will pursue.

The ILD group is actively engaging with other collider proposals under discussion, and is interested to develop and understand how an ILD-like detector would perform at these colliders.

In the past intense cooperation has taken place with the CLIC project. The CLICdp detector concept has many elements from ILD (and SiD). We will continue to work together with other linear collider concepts, for example, the C^3 or the Helen project spearheaded by the US.

Members from ILD have already started to contribute to the FCC-ee study [4], which is gathering momentum in Europe. ILD is open to a strong engagement with FCC-ee, as one possible Higgs-factory proposal, and to study how an ILD-like detector would perform at FCC-ee.

Studies for a detector at the CEPC circular collider have been ongoing since a while. A concept which is based on ILD but has been developed independently from the ILD organization and is available for studies at CEPC [8]. We are interested to continue to cooperate with the relevant groups in the CEPC study, and freely exchange information and know-how.

3. ILD at a Higgs/EW/Top factory: a roadmap

Following the recent European Strategy for Particle Physics [2], a range of activities directed towards a Higgs/EW/Top factory in Europe are starting. The CERN laboratory has started a specific circular collider (FCC) study [4], which is scheduled to deliver intermediate results on the feasibility of FCC in 2024. Studies on possible detectors are part of this study.

ECFA has initiated a series of workshops to explore the scientific and technical implications of a Higgs/ EW/ top factory [9]. The study is not bound to any particular collider proposal, but should study and compare the different options under discussion. Recently a third working group was added to this study group, whose focus is experiments at a Higgs/ EW/ top factory.

ILD has been developed for the ILC, and has been tuned to the particular beam conditions at the ILC. FCC-ee has very different beam parameters, which will impact the way the experiment is operated. ILD is ready to engage with these studies, and to make the case for an ILD-like detector at FCC-ee in particular. Whether or not this will eventually lead to a proposal to FCC-ee for a concrete detector concept should be decided after a period of study and based on the findings of the study. Such a concrete proposal would imply a more formal collaboration than those ILD has previously had with CLIC and CEPC. Depending on circumstances, it may become of interest to initiate similar collaborations with other collider projects.

Whenever possible ILD will look for and try to utilize cooperation with other groups at the other proposed Higgs factories. Whether or not ILD should also formally join forces with any of the discussed concepts should be decided at a later time, based on the results of the study focussed on the development of the ILD concept as laid out in the appendix to this document.

4. ILD infrastructure

The ILD group has traditionally contributed strongly to the development of common software tools, and shared reconstruction packages with non-ILD groups. ILD remains fully committed to an open approach towards software systems, and participates in the development of a common, broadly applicable software framework (Key4hep) to be used by different future collider projects.

As part of the studies directed towards understanding ILD performance at other collider concepts than ILC, ILD will attempt to develop detector models as variants of ILD which can be used for studies at these colliders. For the FCC collider concept in particular, this work may happen in close cooperation with other detector concepts, in particular with the CLD concept.

5. The ILD organization

The ILD organization as defined in the ILD by-laws is not affected by these changes. In particular, the rules governing the use of simulated event data created with ILD models and ILD know-how, and the dissemination of results obtained based on ILD software and models, remains unchanged.

Datasets created using the ILD detector model, shall be used only by people associated with the ILD concept. Scientists from institutes who are not formally members of the ILD group can ask for access by being admitted to ILD as guest members. If close cooperation with another concept group develops, special rules governing this cooperation may be put into place.

Contribution to papers and conferences based on ILD related work shall as usual be approved by the ILD publication and speakers bureau. The ILD publication rules remain unchanged.

6. Bibliography

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[4] CERN. “Home | Future Circular Collider.” *CERN*, https://fcc.web.cern.ch/. Accessed 13 July 2022.

[5] KEK. “Next step toward the ILC realization: MEXT expert panel publishes recommendations.” 高エネルギー加速器研究機構, 25 February 2022, https://www.kek.jp/en/topics-en/202202251335/. Accessed 13 July 2022.

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[7] ILD group. “ILD Strategy meeting I.” *ILD Strategy Meeting I*, 15 April 2020, https://agenda.linearcollider.org/event/9623/. Accessed 13 July 2022.

[8] CEPC. “CEPC Conceptual Design Report: Volume 2 - Physics & Detector - INSPIRE.” *Inspire HEP*, 23 November 2018, https://inspirehep.net/literature/1705023. Accessed 13 July

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Appendix 1. An ILD work program

In a series of discussions and presentations in the late winter / early spring of 2022 [6], ILD has developed a view on a list of open issues which need to be addressed and understood to further optimize ILD, and to also understand the performance of ILD at other colliders, especially circular colliders.

1. The forward tracking region of ILD has a number of shortcomings. A dedicated optimization for this region, in particular of the acceptance of the vertex detector, should be done. This region will also be heavily affected by different environmental conditions at different collider projects, and might need dedicated solutions for each proposal.

2. Circular colliders will have a smaller inter-bunch timing difference than ILC, and also do not deliver bunch-trains, but rather continuous beams. The latter significantly changes the possibility to do power-pulsing for the front-end electronics of the ILD sub-detectors. The current design of the ILD sub-detectors depends crucially on their capability to manage the thermal load through power pulsing. Using the ILD sub-detectors at FCC will require a very detailed study of how the systems can perform without power pulsing, and the development of a concept of how the thermal management can work in this new situation, while minimizing additional dead material in the system.

3. The close inter-bunch spacing and lack of inter-bunch train quiet periods puts additional challenges on the operation of a TPC in this environment. ILD should explore how an ILD-like TPC would perform in these different conditions, and where the limits are for the TPC. Since the TPC adds significant particle identification power in particular at lower center-of-mass energies, this study should focus on the lower range of energies at a Higgs/EW/Top factory.

4. A focus of experimentation at circular colliders is a very high-luminosity Z program. ILD should investigate how well the detector performs under these conditions, and identify components which might need replacement or modification.

5. Circular colliders will have a very different forward region, in order to control the machine backgrounds, and in order to provide the beam focusing. ILD should develop a concept for a forward region compatible with FCC-ee and study the impact this changed region will have on the detector performance.

6. A central challenge for a detector like ILD, optimized for precision physics, is the delivery of an excellent and stable calibration and alignment environment. These considerations need to be included from early on in the design. The different running conditions and beam conditions might impact the way the detector is to be calibrated and aligned, and need to be studied.

The ILD working groups will develop a more detailed work program to be addressed within ILD.