The ILD Detector for the ILC
Letter of Interest for the 2020 Snowmass Process

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Abstract

The International Large Detector, ILD, is a detector proposal developed for an electron-positron collider that starts operation as a Higgs factory, and then expands in energy to run near the top threshold and beyond. It has been optimised for the International Linear Collider, ILC. With its well developed infrastructure for simulation studies ILD is well prepared to support the Snowmass effort.

1. The ILD Detector

The design of the ILD detector is driven by a list of requirements, which have been developed based on the main science topics for which this detector is going to be built [1]:

- **Impact parameter resolution:** An impact parameter resolution of $5\,\mu\mathrm{m} \oplus 10\,\mu\mathrm{m}/[p\,(\mathrm{GeV}/c)\sin^{3/2}\theta]$ has been defined as a goal, where θ is the angle between the particle and the beamline.
- **Momentum resolution:** An inverse momentum resolution of $\Delta(1/p_T) = 2 \times 10^{-5}$ (GeV/c)$^{-1}$ asymptotically at high momenta should be reached with the combined silicon - TPC tracker. Maintaining excellent tracking efficiency and very good momentum resolution at lower momenta will be achieved by an aggressive design to minimise the detector's material budget.
- **Jet energy resolution:** Using the paradigm of particle flow a jet energy resolution $\Delta E/E = 3\%$ should be reached at energies larger than 100 GeV.[1]
- **Hermeticity:** With a special system of forward calorimeters, the ILD detector concept achieves hermeticity down to polar angles of about 6 mrad.
- **Readout:** The detector readout will not use a hardware trigger, ensuring full efficiency for all possible event topologies.
- **Powering:** To allow a continuous readout, and, at the same time, minimize the amount of dead material in the detector, the power of major systems will be cycled between bunch trains.

A focus of the design thus is the full reconstruction of all particles in the events, both charged and neutral, in terms of location, momentum and energy. This led to the fundamental design choices of a high precision highly efficient tracking and vertexing system, with excellent solid angle coverage, and an imaging calorimeter system, located inside the magnet, of very high granularity, allowing to reconstruct and measure neutral particles in jets . As a consequence of these choices the detector is relatively large, to ease the separation of particles in jets (Figure 1 for a schematic of the detector and an event display). A recent review of the ILD design is documented in the interim design report, IDR [2].

ILD needs to be able to cope with the accelerator environment. The current proposal has been optimised for the ILC [1] environment, with detailed studies done for the machine-detector integration, and the implementation of ILD as a detector at the ILC in Japan.

[1] The resolution is defined in reference to light-quark jets, as the R.M.S. of the inner 90% of the energy distribution.

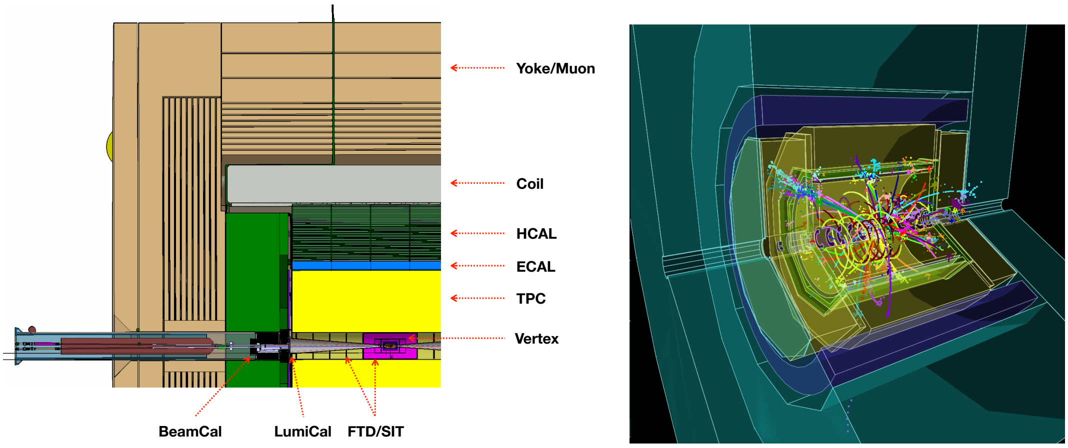

Figure 1: Left: Single quadrant view of the ILD detector. Right: Event display of a simulated hadronic decay of a $t\bar{t}$ event in ILD. The colouring of the tracks show the results of the reconstruction, each colour corresponding to a reconstructed particle.

2. Technologies in the ILD Detector

The ambitious requirements for a detector at the ILC have sparked a world-wide R&D program to develop and demonstrate the different technologies needed [3]. The R&D is mostly coordinated and executed within so-called R&D collaborations, which concentrate on particular technologies and sub-detector systems. The ILD concept group from its beginning has collaborated very closely with these R&D groups (see e.g. [4], [5]).

The current detector baseline design (for details see [2], [6]) has an ultra-light central tracking system, with up to 5 - predominantly pixellated - silicon layers inside a high precision TPC. At a radius of 1.8 m, a particle-flow calorimeter starts, with an electromagnetic section of around 0.25 cm^2 transverse cell size, and 30 layers of tungsten absorbers, followed by between 30 and 48 layers of a highly granular hadronic section, with a cell size of a few cm^2. A detailed model of the detector has been developed in simulation, with the performance of sub-detector systems based on test beam results for all major components.

ILD as a group is actively following technological developments and is studying their impact on ILD. Areas of particular interest at the moment are the use of fast timing, in sub-detectors and in the reconstruction, and of using advanced methods of data readout and handling.

The total detector cost has been estimated to be about 380 M Euros in 2018 costs, including person-power [2].

3. Science with ILD

ILD has been designed to operate at centre-of-mass energies between 90 GeV and 1 TeV. The science goals of the ILC have been described in detail in [7]. Most of the central processes have been studied in detailed analyses based on fully simulated events, using a realistic detector model and advanced reconstruction software, and in many cases, include estimates of key systematic effects. This is particularly important when estimating the reach the ILC and ILD will have for specific measurements. Determining, for example, the branching ratios of the Higgs at the percent level depends critically on the detector performance, and thus on the quality of the event simulation and reconstruction. Many studies however could profit from further work, or have never been done - a summary of some of the uncovered questions is available in [8].

4. The ILD Concept Group

The ILD concept group was formed in 2009 and has since pursued the design development and validation of a detector for an electron-positron collider, in particular, the ILC. At the moment 64 groups from 30 countries and nearly 400 physicists signed the Interim Design Report, another 10 groups have expressed an active interest in the concept.

The group is an open organisation, highly welcoming new members interested in its further development. Joining ILD does not at present depend on commitments, but expresses an interest to contribute to the design of future detectors at an electron positron collider. Recently the ILD group has implemented a guest membership, which makes it very simple for interested people to join the effort to explore a concrete project (see e.g. [8]) on a limited timescale. Guest members will get access to the extensive set of simulated ILD events, which are a valuable resource for studies of the physics scope of future electron positron colliders, and to the fully developed suite of software tools. This is meant to in particular support and help the Snowmass effort.

5. Conclusion and Outlook

The ILD detector concept is a well developed integrated detector optimised for use at the electron-positron collider ILC. A sizeable community interested in building and operating ILD has formed over the last few years. It is ready to take up the challenges indicated by the high priority given by the European Strategy update in 2020 to a Higgs factory. ILD welcomes new members to work on the ILC physics programme, to further improve the ILD design and to move forward once the ILC project receives approval.

References

[1] P. Bambade, et al., The International Linear Collider: A Global Project (3 2019). arXiv:1903.01629.

[2] H. Abramowicz, et al., International Large Detector: Interim Design Report (3 2020). arXiv:2003.01116.

[3] J. Strube, M. Titov, Linear Collider R&D liaison report, http://www.linearcollider.org/physics-detectors/working-group-detector-rd-liaison (2018).

[4] The CALICE collaboration, https://twiki.cern.ch/twiki/bin/view/CALICE/WebHome.

[5] The LCTPC collaboration, http:lctpc.org.

[6] H. Abramowicz, et al., The International Linear Collider Technical Design Report - Volume 4: Detectors (2013). arXiv:1306.6329.

[7] H. Aihara, et al., The International Linear Collider. A Global Project (1 2019). arXiv:1901.09829.

[8] K. Fujii, et al., ILC Study Questions for Snowmass 2021 (7 2020). arXiv:2007.03650, doi:10.3204/PUBDB-2020-02708.