Introduction to Analysis Session

Keisuke Fujii
on behalf of the Physics WG
June 3, 2021

April 14, 2021

Organigram

Software Coordination

Physics Coordination
(Coordinator/Deputy)
=(KF/Filip Zarnecki)

Technical Coordination

Filip as Jenny's successor

Higgs/EW
(2 conveners)
Junping Tlan
Ivanka Bozovic

Ivanka as Graham's successor

Top/QCD/HF
(2 conveners)
Roman Poeschl,
Adrian Irles

Adrian as Ryo's successor

BSM/NP
(2 conveners)
Mikael Berggren
Tomohiko Tanabe

Priority No.1 = to realize ILC

What we need =

- **clear physics case**
- **community supporting ILC**

Priority No. 2 = to realize ILD

What we need =

- **detector design, which is attractive, cost effective, and technically feasible, to realize the physics**

The Goals of Physics Coordination

1) to explore ILC's physics potential and opportunities (= combined effort with IDT WG3),

2) and to optimize ILD so as to prepare for the LOI call and get it approved to realize the physics.

ILD has been the main driving force to input physics simulation results to LCC Physics WG. Let us continue this good tradition also for IDT WG3 by contributing to, for instance, the Snowmass White Paper.

As for the detector optimization, we have finished the IDR round.

Since the new 250 GeV MC production has almost been finished, we need to fully utilize the new samples as well as to plan for the next, aiming at the coming LOI call that should happen in the Pre-Lab period.

Analysis Session Agenda

15:25 - 16:55 CEST

Physics Analysis: Introduction	*Keisuke Fujii*
zoom	15:25 - 15:30
Higgs/EW status and plans	*Ivanka Bozovic-Jelisavcic et al.*
zoom	15:30 - 15:50
Top/QCD/HF status and plans	*Adrian Irles et al.*
zoom	15:50 - 16:10
BSM status and plans	*Mikael Berggren et al.*
zoom	16:10 - 16:30
Discussion	
zoom	16:30 - 16:55

We will hear from each WG its status and plan for the next couple of years.

Backup

ILD Detector Optimisation, Reconstruction and Physics Projects for the IDT Period

https://confluence.desy.de/display/ILD/ILD+Detector+Optimisation%2C+Reconstruction+and+Physics+Projects+for+the+IDT+Period

Detector Design and Alignment

- **re-optimisation of inner silicon tracker design:**
  - **objective:** The efficiency to find secondary vertices in forward direction is limited in current ILD design, e.g. due to relatively large gap between end of VTX barrel and first FTD disk, which is in turn related to the Faraday cage of the VTX and services in this area. Eg CLICdp takes a completely different approach with its "spiraling" forward vertex detector. Could a CLICdp-like approach also improve ILD? Are there other ideas for better - and yet realistic layouts of VTX /FTD? Are there any benefits from making SIT part of the vertex detector?
  - **tools & methodology:** DD4HEP, start from ILD_l5_v02, modify VTX/FTD transition, and/or try to plug-in CLICdp vertex detector. Compare resolutions and efficiencies / purities to ILD_l5_v02, both at track-level and at vertex-level
  - **contact: Roman Poeschl, Marcel Vos**

- **incorporation of fast timing into ILD:**
  - **objective:** With time resolutions at the level of a few 10ps becoming conceivable, a proposal should be made if and how fast timing could be implemented in ILD. Possible use-cases reach from rejection of out-of-time backgrounds via 5D Particle Flow to particle identification (ToF).
  - **tools & methodology:** current ILD simulation and reconstruction provides hits from the SET and the first 10 layers of the ECal with "perfect" timing and smeared by various assumed time resolutions. Based on these, formulate requirements for the various use cases, and estimate potential benefit, discuss these requirements with the relevant sub-detector groups, formulate proposal of how to implement timing in ILD and what R&D would be needed.
  - **contact: Jenny List**

- **tracker alignment:**
  - **objective:** estimate need of tracks to align tracking system eg after push-pull, determine achievable level of precision and residual systematics for standard running scenario, quantify amount of data eg at Z pole to significantly improve residual systematic uncertainties. How many cosmics would reach the deep ILC IP location?
  - **tools & methodology:** Mis-align tracker components in simulation (is supported by DD4HEP) and evaluate impact of various types / sizes of mis-alignments. Develop strategy for track-based alignment. Quantify residual uncertainties as a function of the available luminosity at each energy.
  - **contact: Graham Wilson, Frank Gaede**

Reconstruction and Performance

- **Systematic uncertainties:**
  - **objective:** So far most physics projections are based on either rather ad-hoc assumptions on systematic uncertainties or even on statistical uncertainties only. For a precision machine like the ILC, however, maximizing the control of systematic effects and thereby minimizing their impact on the final physics output should be integral part of the detector (and accelerator) design. Goal is to develop a list of systematics which analyses typically should consider, and develop strategies and tools to estimate and minimize their impact.
  - **tools & methodology:** first list started, methods reach from studies of calibration samples to discussions with subdetector groups / theorists.
  - **contact: Graham Wilson, Marcel Vos, Jenny List**

- **Reconstruction of V0s, kinks & prongs:**
  - **objective:** The reconstruction of in-flight decays incl. V0s, kinks, prongs etc is a special strength of ILD due to its TPC. The current reconstruction exploits this strength only in a very rudimentary fashion. Realiable finding and constrained fitting of such decays will improve the overall reconstruction of jets as well as enable searches for exotic long-lived particles, i.e. from Dark Sector models.
  - **tools & methodology:** full ILD simulation, review, unify and improve treatment of in-flight decays before and after particle flow. Exploit dE/dx for PID, develop constrained fitting.
  - **contact: Daniel Jeans, Graham Wilson, Jenny List**

- **Photon Reconstruction:**
  - **objective:** Reconstructed well calibrated and unbiased estimates of photon 4-vectors with understood measurement uncertainties are essential for more sophisticated uses of photons such as in brems recovery for leptons, mass-constrained fits, pi0 reconstruction, jet error parametrisation etc. Understand and exploit the full potential of a highly-granular ECal, and of the continuous tracking (photon conversions) of ILD.
  - **tools & methodology:** full ILD simulation, review and revise photon calibrations and error estimates apply to cases listed above.
  - **contact: Graham Wilson, Daniel Jeans**

- **Jet clustering with PFO uncertainties:**
  - **objective:** For final-states with more than 2 jets, usually the jet clustering mistakes dominate the JER. Jet algorithms used in ILD are mainly the ones developed for LEP (with the exception of the Valenica algorithm). None of them exploits the full information provided by a particle flow detector, which includes reliable uncertainty estimates for each PFO (aka ErrorFlow) - how can this information be used in jet clustering?
  - **tools & methodology:** Either "classically": develop new distance measures and recombination schemes which take into account ErrorFlow information - or employ machine learning!
  - **contact: Marcel Vos, Jenny List**

Open Topics wrt Physics Potential

- **Triple Gauge Couplings at 250 GeV:**
  - **objective:** Charged triple gauge couplings are among the EW parameters which are tightly connected to the interpretation of Higgs precision data, eg in SMEFT. Already at 250 GeV, ILC is expected to improve substantially over current knowledge, in particular in any interpretation which considers more than one free parameter. Goal is to provide the first comprehensive projection based on ILD full simulation, thereby controling important systematic effects via a nuisance parameter technique which is currently explored based on generator-level distributions.
  - **tools & methodology:** ILD full simulation study at 250 GeV, including all relevant processes (WW, single-W etc), provide acceptance corrected production and decay angle spectra with statistical and systematic uncertainties, incorporation in SMEFT fit.
  - **contact: Jenny List**
- **Dark Sector Discovery Potential at 250 GeV:**
  - **objective:** Comprehensive survey of the ILC capabilities to discover or constrain dark sector models, identify e.g. special detector requirement for exotic signatures, compare reach with other collider and beam-dump experiments.
  - **tools & methodology:** Depending on the channel, either full ILD simulation or SGV, interaction with theorists to define parameter space to be scanned.
  - **contact: Mikael Berggren, Tomohiko Tanabe**
- **Higgs self-coupling at 500-600 GeV:**
  - **objective:** Measurements of the triple-Higgs-coupling from ZHH will be one of the main targets of the second energy stage of the ILC, and is a key argument in the debate of Linear Colliders vs circular ee + hh. Last studies (~10 years old) were severely limited by reconstruction / analyses techniques and do not do justice to the state-of-the-art, therefore an update of the projections will have important impact on the ILC physics case. Furthermore, the impact of the exact choice of center-of-mass energy for the second stage should be evaluated.
  - **tools & methodology:** revisit list of improvements from last analysis (PhD thesis Claude Dürig), study in particular ZZH vs ZHH separation based on state-of-the-art HLR and at 500, 550 and 600 GeV, investigate gain by machine learning.
  - **contact: Jenny List, Junping Tian**
- **Top Yukawa Coupling at 500-600 GeV:**
  - **objective:** Measurements of the top-Yukawa-coupling from ttH will be one of the main targets of the second energy stage of the ILC. Last studies (~10 years old) were severely limited by reconstruction / analyses techniques and do not do justice to the state-of-the-art, and a center-of-mass energy somewhat above 500 GeV could improve the expected precision by factors. Therefore an update of the projections will have important impact on the ILC physics case.
  - **tools & methodology:** Revisit full simulation analysis at 500, 550 and 600 GeV, with state-of-the-art high-level reconstruction and explore potential gain by machine learning.
  - **contact: Tomohiko Tanabe, Junping Tian**
- **Higgs self-coupling at 1 TeV:**
  - **objective:** This measurement may, depending on the actual value of the triple-Higgs-coupling chosen by nature, provide the final ILC precision on this important parameter. Again, existing studies do not reflect the state-of-the-art reconstruction and analyses techniques. In particular differential measurements have not been explored.
  - **tools & methodology:** Full simulation of nunuHH and ZHH plus most important backgrounds with up-to-date reconstruction, apply advanced analysis techniques, explore ML, etc
  - **contact: Jenny List, Junping Tian**