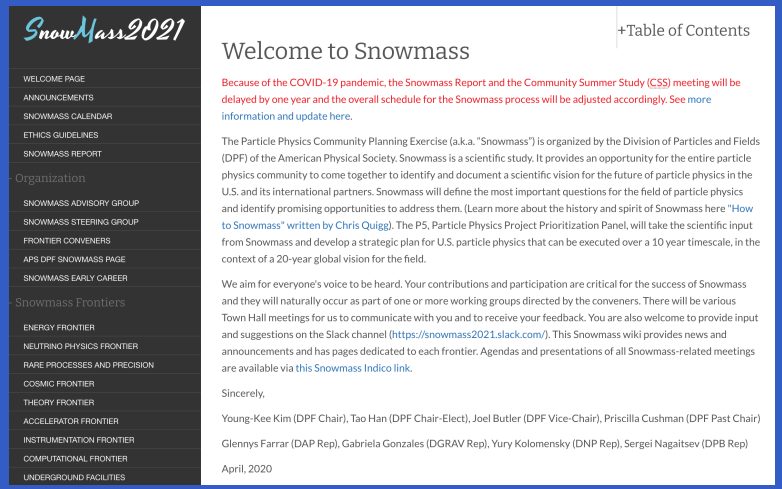
ILC IDT: Higgs Properties Status and Plans



Shinya Kanemura, Patrick Meade, Chris Potter, Georg Weiglein

University of Oregon

Snowmass ILC Simulation Resources

ILC Simulation Resources for Snowmass 2021

This page gives links to the various resources that the ILC physics and simulation working groups are making available for projects on e+e- collider physics for the US community study Snowmass 2021. This page is being actively updated and documentation is being improved, so please check regularly for additional resources and documentation.

- **"ILC Study Questions for Snowmass 2021"**, arXiv:2007.03650 [hep-ph]
  This document presents a collection of open questions for possible Snowmass projects, describes our software framework, and provides contact information. It is a good place to start to learn about physics at ILC, and to get inspired to roll up your sleeves and get studying!

If you have additional questions, either post to the #ilc-snowmass channel on the snowmass2021 slack workspace, or send an email to ilcsnowmass@slac.stanford.edu.

Tutorials

A number of hands-on tutorials were developed for the benefit of Snowmass participants who wish to study ILC-related physics questions. The various tools and samples listed below were introduced, using simple step-by-step examples.
If you are new to ILC physics analysis, this is the place to start learning.
Recordings of the tutorials and the materials used can be found at the following links.

- MC/Simulation Framework Tutorial: ILC [General overview and introduction; held on Aug 28, 2020]
- MC/Simulation Framework Tutorial: Whizard for e+e- [MC event generation; Sept 28, 2020]
- MC/Simulation Framework Tutorial: ILC Analysis Walkthrough [Fast ILC detector simulation, example analysis; Oct 14, 2020]

Tools

http://ilcsnowmass.org [Clickable Link]

ILCX2021: Higgs Properties (Shinya Kanemaura)

F: Higgs Properties Summary

Shinya Kanemura
大阪大学
OSAKA UNIVERSITY

Osaka Univ.
Dr. Wani

ILCX2021 online, October 29, 2021

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34 Speakers

F&H-1 J. Rishabh, Y. Omura, Y. Mura, M. Kakizaki, K. Hidaka
F&H-2 T. Robens, J. Klamka, F. Arco, R. Florentino, C. Li
F1 C. Potter, K. Yagyu, J. Zhou, P. Pasquini, R. Nagai, Y. Uchida
F2 K. Yagyu, R. Sarkar, G. Mishima, M. Takeuchi, D. Harada, M. Tanaka
F3 E. Antonov, M. Aiko, Y. Radkhorrami, Y. Aoki, K. Hashino, H. Shibuya
F4 J. Braathen, T. Shindou, K. Mawatari, P. Sanyal, M. Aiko, K. Sakurai

Thank all speakers for their nice contributions

20minutes, usual apologizes …

2

Contributions to Higgs Properties at ILCX2021

- Simulation studies of the SM Higgs/EFT at ILC
- Extended Higgs sector
- Higher order calculations
- Higgs potential, 1st OPT, EW baryogenesis

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Summary

- Higgs sector is an important window to new physics

- EFT approach
- Extended Higgs sectors/new physics models
- Search for new states
- New no-lose theorem Deviation → New Physics Scale

- Nature of EWSB to be clarified
- EW Baryogenesis (physics at EW phase transition)
  - First Order Phase Transition
  - CP violation

ILC! ILC! ILC!

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ILCX2021: SiD Status and Plans (Chris Potter)

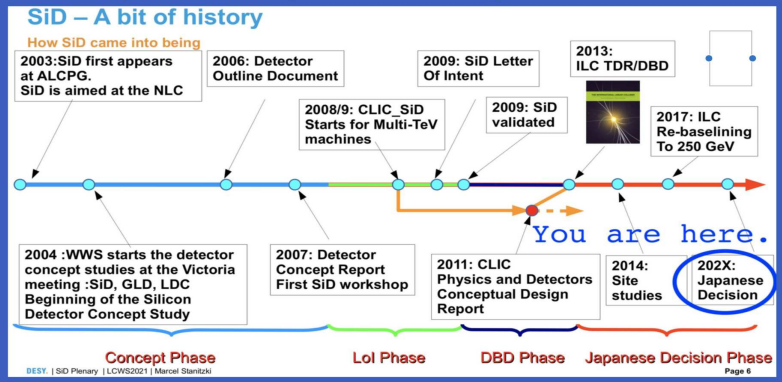
SiD: Status, Concrete R&D, and Longterm Wishes

Chris Potter, on behalf of the SiD Consortium

University of Oregon

SiD: From NLC to TDR/DBD to Decision

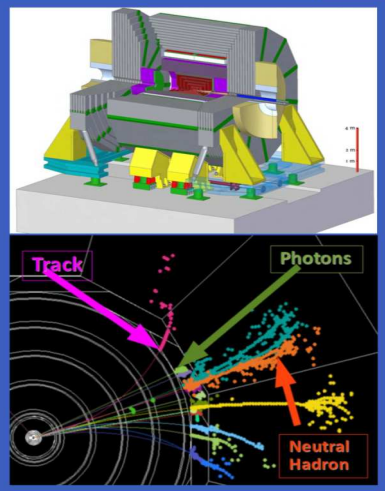
SiD has developed over a period of two decades and has been guided by continuous attention to physics goals. Detector subsystem performance has been verified with hardware prototypes in test beams. Still, performance can improve with new technologies. See arXiv:2110.09965.



Marcel Stanitzki, LCWS2021

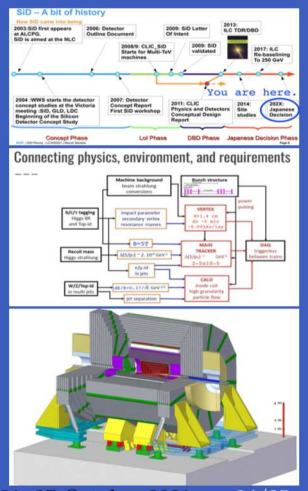
Updated SiD Design: arXiv:2110.09965

- SiD was designed to take advantage of the particle flow technique. This requires the calorimetery to be placed inside the solenoid.
- The vertex detector, tracker and electromagnetic calorimeter (ECal) use silicon strips and pixels.
- The use of Monolithic Active Pixels (MAPS) for improved performance and reduced cost is now under investigation.
- The updated hadronic calorimeter (HCal) now uses scintillator rather than RPCs, and the readout is now analog rather than digital.
- The iron yoke is now dodecahedral rather than octahedral, and the barrel/endcap interface is now at 30 degrees rather than vertical.



Summary and Conclusion

- SiD has been adapting to physics goals and technology advances over two decades.
- In 2013 the Detailed Baseline Design was fully documented in the ILC TDR.
- Hardware prototypes have been validated in test beams at SLAC and DESY.
- The SiD concept has been updated aiming for enhanced performance and cost reduction, with a rigorous plan for optimization.
- Key updates include (arXiv:2110.09965):
  - Proposal for R&D for MAPS sensors for vertex detector, tracker and ECal
  - Move to analog HCal readout with scintillators sensors
  - Move to dodecahedral iron yoke and a 30 degree barrel/endcap interface
- We hope to attract collaborators for continued development of SiD in the context of a realized ILC in Japan.



ILCX2021: SiD Snowmass LoIs (1)

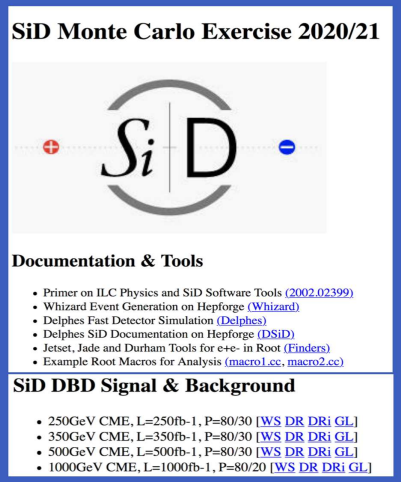
Status: SiD Snowmass Studies on Higgs Properties

Chris Potter [a]

University of Oregon

[a]For Snowmass LoI authors Tim Barklow, Jim Brau, Lucas Braun, Masako Iwasaki, Laura Jeanty, Masakazu Kurata, Laura Nosler, Peter Onyisi, Austin Pryor, Amanda Steinhebel, Andy White

SiD Monte Carlo Exercise 2020/21



SiD Monte Carlo Exercise 2020/21

Documentation & Tools

- Primer on ILC Physics and SiD Software Tools (2002.02399)
- Whizard Event Generation on Hepforge (Whizard)
- Delphes Fast Detector Simulation (Delphes)
- Delphes SiD Documentation on Hepforge (DSiD)
- Jetset, Jade and Durham Tools for e+e- in Root (Finders)
- Example Root Macros for Analysis (macro1.cc, macro2.cc)

SiD DBD Signal & Background

- 250GeV CME, L=250fb-1, P=80/30 [WS DR DRi GL]
- 350GeV CME, L=350fb-1, P=80/30 [WS DR DRi GL]
- 500GeV CME, L=500fb-1, P=80/30 [WS DR DRi GL]
- 1000GeV CME, L=1000fb-1, P=80/20 [WS DR DRi GL]

SiD MC20 Signal

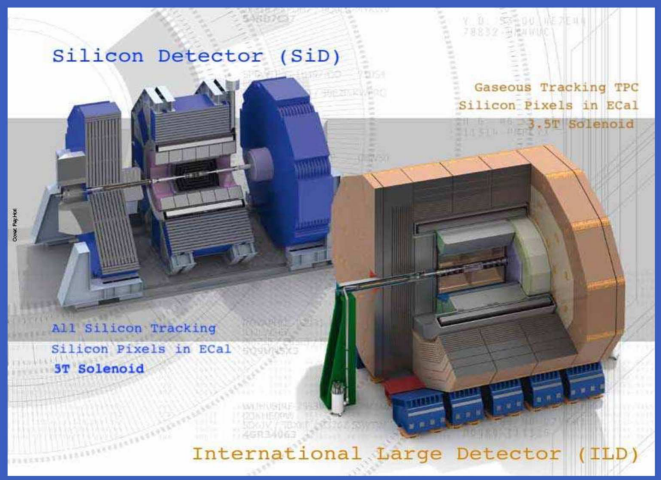
- 250 GeV CME, L=2x100ab-1, P=80/30
  - SM Single Higgs, Inclusive H [WS DR DRi GL]
  - SM Single Higgs, H to Tau Pairs, Inclusive Tau [MH DR DRi GL]
  - BSM Higgs, H to Invisible [WS DR DRi GL]
- 350 GeV CME, L=2x100ab-1, P=80/30
  - SM Single Higgs, Inclusive H [WS DR DRi GL]
  - SM Top Pair, Inclusive Top [WS DR DRi GL]
- 500 GeV CME, L=2x100ab-1, P=80/30
  - SM Single Higgs, Inclusive H [WS DR DRi GL]
  - SM Double Higgs, Inclusive H [WS DR DRi GL]
- 1000 GeV CME, L=2x10^5 ab-1, P=80/30
  - SM Double Higgs, Inclusive H [WS DR DRi GL]

SiD MC21 Signal & Background

- 250 GeV CME, L=2x1ab-1, P=80/30
  - Signal Higgs
    - BSM Higgs, H to Dark Photons [MH DR DRi GL]
  - Two Fermion Backgrounds
    - 2f e-e+->qq,l+l- [WS DR DRi GL]
  - Three Fermion Backgrounds
    - 3f e-A->Ze-,νW- [2x10ab-1] [WS DR DRi GL]
    - 3f Ae+->Ze+,νW+ [2x10ab-1] [WS DR DRi GL]
  - Four Fermion Backgrounds
    - 4f e-e+->WW [WS DR DRi GL]
    - 4f e-e+->Wev [WS DR DRi GL]
    - 4f e-e+->ZZ [2x10ab-1] [WS DR DRi GL]
    - 4f e-e+->Zee [WS DR DRi GL]
    - 4f e-e+->Zνν [2x10ab-1] [WS DR DRi GL]
- 350 GeV CME, L=2x1ab-1, P=80/30
- 500 GeV CME, L=2x1ab-1, P=80/30
- 1000 GeV CME, L=2x1ab-1, P=80/20

SiD Monte Carlo 2020/21 Page [Clickable Link]

SiD and ILD: ILC TDR Volume 4



SiD Snowmass Physics LoIs: Status

- Higgs to Invisible at $\sqrt{s} = 250$ GeV
  - Results with full SiD simulation and BDT presented to the SiD Optimization meeting.
  - Both hadronic and leptonic channels are now included with BDT analysis.
- Higgs CP in Tau Pairs at $\sqrt{s} = 250$ GeV
  - Preliminary results with fast simulation, preparing to study full SiD simulation.
  - Progress presented to the biweekly SiD Optimization meeting convened by the University of Glasgow (Dan Protopopescu and Aidan Robson).
- Higgs to Long-lived Dark Photons at $\sqrt{s} = 250$ GeV
  - Results with fast simulation, samples generated with full SiD simulation in validation.
  - Collaboration with Snowmass colleagues at Brookhaven National Lab is ongoing.
- Higgs Self-coupling at $\sqrt{s} = 500, 1000$ GeV
  - Fast/full SiD simulation at $\sqrt{s} = 500, 1000$ GeV for double Higgs is ready.
  - Reconstruction of secondary vertices with the `LCFIPlus` package is in validation.
- Your participation in these studies would be welcomed! Contact the SiD Co-spokes Andy White (awhite@uta.edu) and Marcel Stanitzki (marcel.stanitzki@desy.de).

ILCX2021: SiD Snowmass LoIs (2)

Higgs to Invisible at $\sqrt{s} = 250$ GeV with SiD

LOI - ILC/SiD Higgs to Invisible

Andrew White, Austin Prior, University of Texas at Arlington,
James Brau, Christopher Potter, Amanda Steinhebel, Makayla Massar, University of Oregon

August 2020

1 Introduction

The Higgs Boson, being the only true scalar particle yet discovered, is a fundamentally new entity in the world of high energy physics. As such, it imperative to explore every aspect of the Higgs properties. While, so far, experimental results are in line with the Higgs having the properties expected in the Standard Model, there is significant room for connections to new physics beyond the Standard Model. This LOI describes a study of possible decays of the Higgs into invisible particles, such as might comprise the Dark Matter.

2 The search for invisible decays of the Higgs

The ATLAS and CMS experiments at the LHC have searched for invisible decays of the Higgs in a variety of channels. The current best limit, from a single search, is from ATLAS in the vector boson fusion process [2]. The limit set is 13% at 95% c.l. This limit has, in turn, been used to set a limit as a function of mass on the dark matter-nucleon scattering cross-section, as seen in Figure 1.

SNOWMASS21-EF2_EF1_Andy_White_Jim_Brau-185 [Clickable Link]

Higgs CP at $\sqrt{s} = 250$ GeV with SiD/ILD

Measuring the CP properties of the Higgs sector at electron-positron colliders

D. Jeans (KEK) [daniel.jeans@kek.jp]
I. Bozovic-Jelisavcic, G. Milutinovic-Dumbelovic
(Vinca Institute of Nuclear Sciences, Belgrade)
J. Brau, L. Braun, C. Potter (University of Oregon)

August 31, 2020

Letter of Interest for SnowMass2021: Energy Frontier

The violation of the CP symmetry is one of Sakharov's conditions for the matter–anti-matter asymmety of our universe. Currently known sources of CP violation in the quark and neutrino sectors are too small to account for this. Is CP also violated in the Higgs sector? Is the 125 GeV mass eigenstate a mixture of even and odd CP states of an extended Higgs sector, or is CP explicitly violated in Higgs interactions. With what precision could such effects be measured at future electron-positron colliders?

Several processes at e^-e^+ colliders are sensitive to the CP nature of the Higgs sector. Some are sensitive to fermionic, others to bosonic couplings; they also require different centre of mass energies, as summarised below.

SNOWMASS21-EF1_EF2_DanielJeans-113 [CLickable Link]

Higgs to LLP at $\sqrt{s} = 250$ GeV with SiD

Sensitivity to decays of long-lived dark photons at the ILC

Laura Jeanty, Laura Nosler, and Chris Potter
University of Oregon
(Dated: August 28, 2020)

I. INTRODUCTION

Searches for light, weakly coupled particles are an important component of the physics program at present and future colliders. New hidden or dark sectors around the electroweak scale which are weakly coupled to the Standard Model (SM) through mediators are well motivated by numerous theoretical and observational considerations, including naturalness, dark matter, and electroweak baryogenesis. A classic benchmark for a potential vector-boson mediator between the SM and dark sector is the hypothetical dark photon, γ_D, which interacts with the SM through kinematic mixing with the weak hypercharge field B with coupling strength ϵ. The dark sector could also have a dark Higgs boson, h_D, which in the general case will mix with the SM Higgs Boson [1]. This opens up a Higgs portal production mode for dark photons.

of long-lived γ_D as a benchmark to study the detector performance for detection of displaced decays.

II. QUESTIONS TO STUDY

We plan to focus on the proposed ILC dataset of 2 ab^{-1} at $\sqrt{s} = 250$ GeV. We are interested to use truth-level signal simulation samples to explore the full acceptance available to the ILC detectors. To explore the expected detector performance, we aim to use a benchmark signal sample reconstructed with full simulation of the SiD detector. The nominal SiD vertex detector [5] comprises five barrels closed by four disks one each side, together with three more forward disks further along the beamline on each side. Barrels and disks are instrumented with Silicon pixels with 5 μm or better hit resolution [5]. Comparisons of truth-level acceptance and full simulation with the standard recon-

SNOWMASS21-EF9_EF8-081 [Clickable Link]

Higgs Self-Coupling at $\sqrt{s} = 500, 1000$ GeV

Higgs Self-Coupling at the ILC with the SiD Detector
(A Snowmass 2021 Leter of Interest)

Tim Barklow[1], James Brau[2,3], Masako Iwasaki[4,5,6,7], Masakazu Kurata[8], Peter Onyisi[9], and Chris Potter*[2,3]

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[3]Institute for Fundamental Science, University of Oregon, Eugene, Oregon 97403-1274, USA
[4]Department of Mathematics and Physics, Graduate School of Science, Osaka City University, Osaka, Japan
[5]Nambu Yoichiro Institute of Theoretical and Experimental Physics (NITEP), Osaka City University, Osaka, Japan
[6]Research Center for Nuclear Physics (RCNP), Osaka University, Osaka, Japan
[7]Osaka University Institute for Datability Science (IDS), Osaka, Japan
[8]Graduate School of Science, University of Tokyo, Tokyo, Japan
[9]Department of Physics, University of Texas at Austin, Austin, Texas 78712, USA

August 31, 2020

Abstract

Measuring the Higgs boson self-coupling λ_{hhh} with high precision is an important part of the program for particle physics in the coming decades. In the Standard Model (SM), $\lambda_{hh}^{SM} = m_h^2/2v^2$ is determined by two parameters, $v = (\sqrt{2}G_F)^{1/2} \approx 246$ GeV and $m_h \approx 125$ GeV. In Beyond the SM (BSM) scenarios, new particles can enhance or diminish the self-coupling through mixing or in loops. In e^+e^- colliders λ_{hhh} is measured by measuring the cross section for double Higgs production $e^+e^- \to ZHH$ or $e^+e^- \to \nu\bar{\nu}HH$. In this study we investigate the expected sensitivity to λ_{hhh} at the ILC with the SiD detector.

SNOWMASS21-EF1_EF_Potter-155 [Clickable Link]

ILCX2021: SiD Snowmass LoI Status

SiD Snowmass Physics LoIs: Status

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ILCX2021, 27 October 2021 – p.18/18

See also Valentina Cairo's talk on Higgs to strange studies in this session.