

# Report from Physics WG

Keisuke Fujii  
on behalf of the Physics WG  
May 10, 2017

# ILD Physics Coordination Meeting

*on April 11 (Tue.) 20:00-21:00 JST*

## Agenda

1. EPS (July 5-12) talks (abstract deadline: April 15)
  - Precision Higgs Measurements at the 250 GeV ILC: in light of staging -> **accepted**
  - The Potential of the ILC for Discovering New Particles: ICFA support document -> **accepted**
  - Toward Precision Top Quark Measurements in  $e^+e^-$  collisions: ILC/CLIC combined -> **accepted**
  - Precision EW (incl. TGC, etc.) if we have enough manpower to put into this -> **poster?**
  - “Semi-private” talks
    - Higgs:  $HVV$  -> **?**
    - Higgsinos -> **accepted**
    - $e^+e^- \rightarrow b\bar{b}$  -> **poster?**
    - ...
- APS DPF (1st week of Aug.) (abstract deadline: May 12)
  - to be handled by Kiyotomo and Jim?

# ILD Physics Coordination Meeting

## *continued*

### 2. Papers in preparation

- CP mixture in  $H \rightarrow \tau^+ \tau^-$  : Daniel
- $e^+e^- \rightarrow b\bar{b}$  : Roman / Francois
- CPV in Top : Marcel
- Higgsinos : Jackie / Suvi
- Higgs self-coupling : Claude / Jumping / Masakazu
- Anomalous HVV couplings : Tomohisa / Junping
- ...

# BSM Subgroup Status

- **Applying SGV samples for  $\gamma\gamma \rightarrow 2f$  and  $\gamma e \rightarrow 3f$  background processes to analysis**

Last step (?) before finalizing results

- **Abstract accepted for EPS-HEP 2017**

"Naturalness and light Higgsinos: why ILC is the right machine for SUSY discovery"

- in track "Higgs and New Physics" (Parallel Talk). <http://eps-hep2017.eu/>
- Authors: Jacqueline Yan, Jenny List, Mikael Berggren, Suvi-Leena Lehtinen, Howard Baer, Tomohiko Tanabe, Keisuke Fujii

(see next page)



Abstract ID : 344

## Naturalness and light Higgsinos: why ILC is the right machine for SUSY discovery

### Content

Radiatively-driven natural Supersymmetry, a theoretically and experimentally well-motivated framework, centers around the predicted existence of four light, nearly mass-degenerate Higgsinos with mass  $\sim 100\text{--}200$  GeV (not too far above  $m_Z$ ). Their small mass splittings of at most 20 GeV implies very little visible energy of accompanying Standard Model particles decayed from heavier Higgsinos. Given that other SUSY particles are considerably heavy, this makes detection challenging at hadron colliders. On the other hand, the clean environment of an electron-positron collider with  $\sqrt{s} > 2m_{\text{Higgsino}}$  would enable a decisive search of these required Higgsinos, and thus either the discovery or exclusion of natural SUSY. We present a detailed simulation study of precision measurements of Higgsino masses and production cross sections at  $\sqrt{s} \simeq 500$  GeV of the proposed International Linear Collider currently under consideration for construction in Japan. The study is based on a Geant4 simulation of the International Large Detector concept. We examine several benchmark points just beyond the HL-LHC reach, with a mass spectrum containing four light Higgsinos directly accessible by the ILC, and the mass differences between the lightest SUSY particle and the heavier states ranging from about 4 to 20 GeV. It can be shown that their masses and production cross sections are able to be precisely measured to approximately 1% precision or better. These precise measurements allow for extracting the underlying weak scale SUSY parameters. The fitted parameters give predictions for the masses of heavier SUSY states, which provide motivation for future high-energy colliders. Additionally, dark matter properties may be derived. Evolution of the measured gaugino masses to high energies should allow one to distinguish the hypothesis of gaugino mass unification from other compelling possibilities such as mirage mediation.

# ILD Physics Coordination Meeting

## *continued*

### 3. Subgroup meetings

- 1st BSM WG meeting on March 1
- regular subgroup meetings are probably overkill → have one as needed
- effective use of confluence

### 4. MC production → Hiroaki's talk on Apr.24 Lyon Mtg.

### **5. Staging**

### 6. Physics/optimization session of the Lyon meeting

- status reports from individual benchmark studies
- complementary to SLAC WS
- high level rec. session to be co-organized with the software WG

# ***ILD Software & Technical Meeting***

***April 24-28, Lyon***

<https://agenda.linearcollider.org/event/7520/timetable/>

## ***Priority No.1 = to realize ILC***

**What we need =**

- clear physics case**

## ***Priority No. 2 = to realize ILD***

**What we need =**

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



***We have selected benchmark processes with these two goals and the 500 GeV machine in mind.***

# ***Staging Discussion***

- In LCWS 2016, Nov. in Morioka, it was agreed to start seriously considering a staging scenario of the ILC ***to significantly reduce the initial construction cost.***
  - 1st stage as a Higgs factory
  - and later stages taking advantage of flexible energy expandability of a linear collider.
- LCB/LCC started working on possible staging scenarios to build consensus among the worldwide HEP community.

***The major parts (expensive parts, in particular) of the detector should be usable at the higher energies after upgrades.***

***The current benchmark processes are thus still useful and should not be abandoned.***

***However,***

***no upgrade will be included in the budget request of the initial ILC proposal, though upgrades will be mentioned.***

***Any upgrade will be proposed after achieving the milestones for the initial 250 GeV stage.***

**We need to make  
the 1st 250 GeV  
stage as attractive  
as possible!**

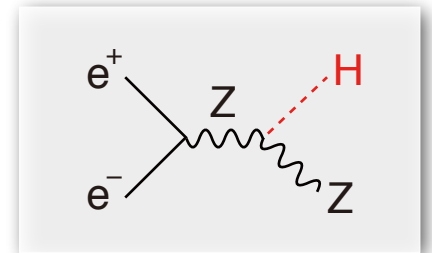
***There is the reason why the ILC has been defined to be a 500 GeV machine, though the value “500” is symbolic and its exact value can be slightly different.***

# Higgs-related Physics at $E_{cm} \approx 500 \text{ GeV}$

## Three well know thresholds

### ZH @ 250 GeV ( $\sim M_Z + M_H + 20 \text{ GeV}$ ) :

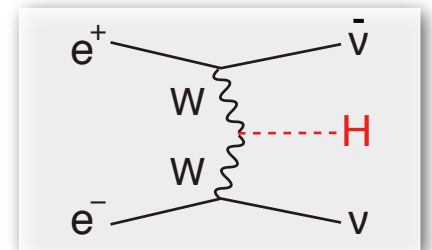
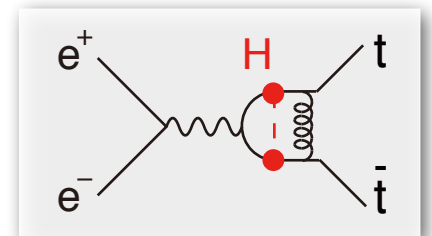
- Higgs mass, width,  $J^{PC}$
- Gauge quantum numbers
- Absolute measurement of HZZ coupling (**recoil mass**)  $\rightarrow$  **Higgs couplings (other than top)**
- $BR(h \rightarrow VV, qq, ll, \text{invisible})$  :  $V=W/Z$ (direct),  $g, \gamma$  (loop)



### ttbar @ 340-350 GeV ( $\sim 2m_t$ ) : ZH meas. Is also possible

- Threshold scan  $\rightarrow$  **theoretically clean  $mt$  measurement**:  $\Delta m_t(\overline{MS}) \simeq 100 \text{ MeV}$   
 $\rightarrow$  test stability of the SM vacuum  
 $\rightarrow$  **indirect meas. of top Yukawa coupling**
- $A_{FB}$ , Top momentum measurements
- Form factor measurements

$\gamma\gamma \rightarrow HH$  @ 350 GeV possibility



### vvH @ 350 - 500 GeV :

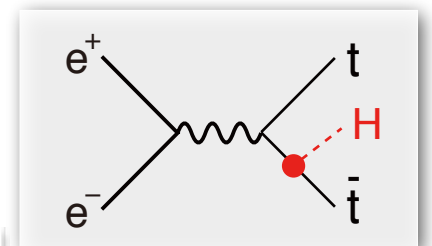
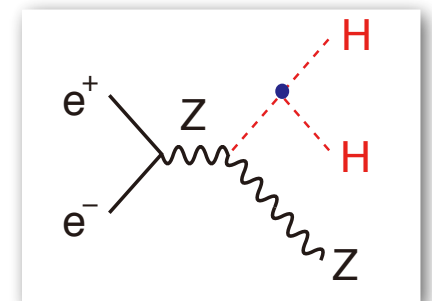
- **HWW coupling**  $\rightarrow$  **total width**  $\rightarrow$  absolute normalization of Higgs couplings

### ZHH @ 500 GeV ( $\sim M_Z + 2M_H + 170 \text{ GeV}$ ) :

- Prod. cross section attains its maximum at around 500 GeV  $\rightarrow$  **Higgs self-coupling**

### ttbarH @ 500 GeV ( $\sim 2m_t + M_H + 30 \text{ GeV}$ ) :

- Prod. cross section becomes maximum at around 800 GeV.
- QCD threshold correction enhances the cross section  $\rightarrow$  **top Yukawa** measurable at 500 GeV concurrently with the self-coupling



**We can access all the relevant Higgs couplings  
at  $\sim 500 \text{ GeV}$  for the mass-coupling plot!**

***We will miss the 2nd and the 3rd thresholds and physics intended there in the 1st stage!***



# Issues and Possible Measures to Address Them

Fully model independent Higgs total width determination needs WW fusion (small at 250GeV)

- **Improve  $\sigma$  BR( $h \rightarrow WW^*$ ) precision**
- **Use ratios of BR's**
- Assume **Custodial Symmetry** that relates  $\Gamma(hWW)$  and  $\Gamma(hZZ)$  (**EFT analysis**)
- Note that **WL and ZL are from the Higgs sector.** → **Global analysis including PEWO** (mW, TGC) in **EFT**

Self coupling measurement needs 500 GeV. How can we address EWBG in the 1st stage?

- **Precision  $hZZ$  coupling measurement?** (EWBG models with singlet mixing)
- **Synergy with GW measurements?**
- CPV in Higgs sector, but we need to know **amount of CPV needed?**

Top/QCD: 1st stage is below  $t\bar{t}$  threshold

- **Use bottom** as the other member of the 3rd generation:  $\sigma(bb)$ ,  $A_{FB}(bb)$
- Single top production?

BSM: Direct search limited by  $E_{cm}$

- **Exotic Higgs decays** to new light particles, FCNC decays ( $\tau\mu$ ,  $bs$ )?
- **Dark Matter** (Z portal, leptophilic DM)
- **Extra light states** (spin-less bosons, dark photon, ..)
- Higgsinos
- Indirect searches using **2-fermion processes** ( $Z'$ )

Physics interpretations/implications with **inputs from theorists**

**Synergies with LHC** (assuming that ILC will be concurrently running with HL-LHC) and other experiments.

# ***Priority and Working Assumptions***

## **Priority**

- ***To make the 1st 250 GeV stage as attractive as possible.***

## **How?**

- **Pursue as high luminosity as possible** by re-optimizing the machine parameters at the cost of higher beam induced background. → Parameter space being investigated (Daniel's talk)
- **Re-optimize the milestones and analysis strategy for the 1st stage.**  
→ A short (2-page) report (*a straw man staging scenario*) handed to Jim Brau, shown on Feb.16 at the ICFA annual meeting in Valencia → Feed back from Jim to LCC Physics WG.

## **ILC Parameters Joint WG met on Mar. 8 → action plan formulated.**

- ***Luminosity optimization at 250 GeV → >50% luminosity increase by halving the horizontal emittance.***
- ***Realistic run scenarios being prepared: starting from 250 GeV then after lumi-up either to 350 or directly to >500 GeV : 2 ab<sup>-1</sup> @ 250 GeV***
- ***Final report expected in late May to early June in phase with the report from Asai's subcommittee set up by JHEPC.***

***It is practically impossible to finish up full fledged 250 GeV full simulation studies by the end of May. We thus have to rely heavily on extrapolations from studies done at higher energies.***

***Nevertheless, it is nice/desirable if we can show full simulation results at the LCWS 2017.***

***Besides, most benchmark processes can be studied at 250 GeV except for the  $t\bar{t}$  production.***

# Ongoing and Planned 250 GeV Analyses

## Higgs

- **Improve  $\sigma$  BR( $h \rightarrow WW^*$ ): Mila Pandurovic?**
- EFT analyses: Tomohisa Ogawa
- $e^+e^- \rightarrow H\gamma$ : Yumi Aoki
- $H \rightarrow \tau\tau$ : Daniel Jeans
- $H \rightarrow$ invisible: Yu Kato
- **$H \rightarrow$ exotic (new light particles, FC/LFV): ?**

## Precision EW

- $m_W$ : Robert Karl
- 2-fermion processes:  $\mu\mu$ : Hirokazu Yamashiro (Taikan Suehara)
- **TGC: Robert Karl?**

## Top/QCD

- $bb$ : Sviatoslav Bilokin
- **Single top production: ?**

## BSM: Direct search

- Dark Matter: Moritz, Tomohiko, Masakazu, ..
- **Extra light states** (light extra higgses, dark photon, ..)
  - **ZX ( $m_X < 125\text{GeV}$ ): Yan Wang**
- Higgsinos: Jackie + Swathi (for very low  $\Delta M$ )

# Topic Covered in The Lyon Meeting

- PID tools: Strahinja Lukic
- $e^+e^- \rightarrow b\bar{b}$ : Sviatoslav Bilokin
- Top EW couplings: Marcel Vos
- WIMP search and  $L^*$ : Moritz Habermehl
- $\gamma\gamma \rightarrow l\bar{l}$  pt hadrons: Swathi Sasikumar
- EW precision measurements: Graham had to cancel the talk
- Higgs precision measurements: Junping Tian
- $H \rightarrow \mu\mu$ : Shin-ichi Kawada
- Impact of Lumi-spectrum on Mrec and MDI: Daniel Jeans
- ***Discussion at the end***
  - ***Re-prioritization of the current benchmark processes?***  
***Is 250 GeV simulation feasible in due time?***  
***(We would use DBD samples + new signal samples with the old framework)***
  - ***New 250 GeV analyses, which are currently not covered?***
  - ***Possible detector staging***  
***for cost reduction at the initial stage?***  
***or for optimization for the 250 GeV?***

# ***ILD Physics WG Confluence Page***

<https://confluence.desy.de/display/ILD/ILD+Physics+Working+group>

# ***Physics focus schedule***

**May 10: BSM (KF) (today)**

May 24: Top/QCD (Akiya)

Jun 7: Higgs/EW (Frank)

Jun 21: AWLC17 rehearsal (Jenny)

**Conveners' ML:**

[ild-physics-conveners@desy.de](mailto:ild-physics-conveners@desy.de)

***Use this mailing list to send your talk request.***