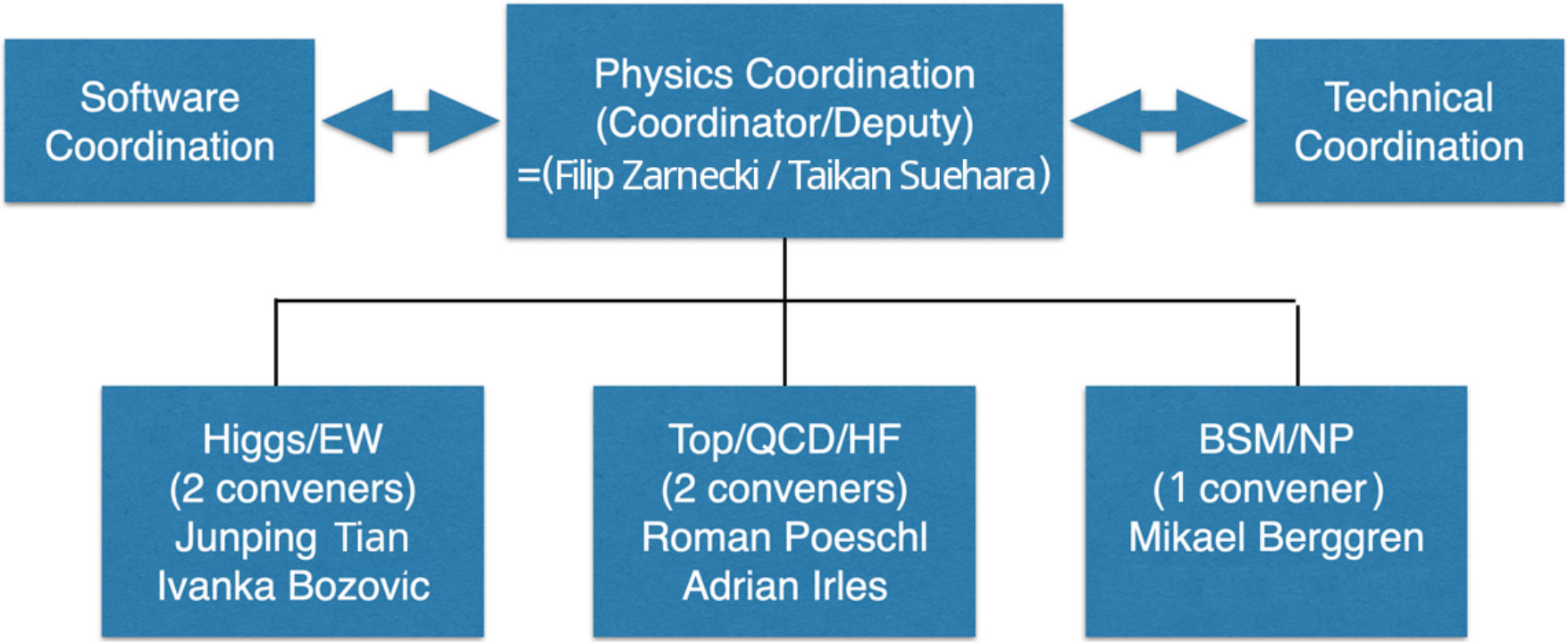
Status of ILD analyses
Report from ILD Physics Working Group

Aleksander Filip Żarnecki
on behalf of the Physics WG conveners

ILD meeting at LCWS2023
May 17, 2023

ILD Physics Working Group

Group structure from April 1, 2023



Many thanks to Keisuke Fujii for his leading role, over the last years, in coordinating ILD physics activities and shaping of the ILD physics program

Many thanks to Taikan for joining the group management team

Our goals

Main goals of the ILD physics working group are

- to make compelling physics case for ILC
  convince decision makers that ILC is worth the investment
- to optimize the ILD detector design
  to make full use of the ILC physics potential

Our goals

Main goals of the ILD physics working group are

- to make compelling physics case for ILC
  convince decision makers that ILC is worth the investment
- to optimize the ILD detector design
  to make full use of the ILC physics potential

But we also need to take "secondary" targets into account

- physics case for the e^+e^- Higgs Factory in general
  contribute to the ECFA Higgs/EW/Top factory study
- challenges to use ILD at other colliders
  defined recently as one of our priorities

Analysis highlights

Measurement of Br($H \to Z\gamma$) at the 250 GeV ILC, E.S. Antonov and A.G. Drutskoy, Published in JETP Lett. 117 (2023) 3, 177-183, arXiv:2212.07889

After weighting and applying all cuts the M_Δ distributions is obtained for $\mathcal{P}_{e^-e^+} = (-0.8, +0.3)$ with $2\ ab^{-1}$ integrated luminosity.

The signal distribution was described by the convolution of Breit-Wigner and Gaussian functions + additional wide Gaussians to describe both tails:

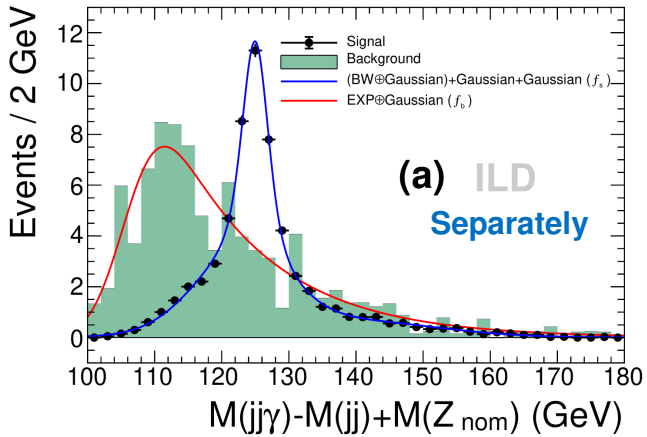
$$F_S(m) = f_1\,\mathrm{BW}\otimes G_1 + (1-f_1)\times[f_2\,G_2 + (1-f_2)\,G_3]$$

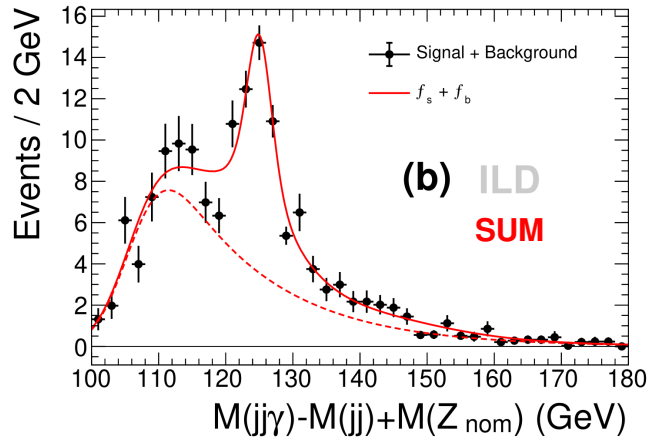
The background distribution is described by:

$$F_B(m) = exp(-m/\tau)\otimes G_4$$

The fit yields 60 ± 13 signal events for $2\ ab^{-1}$ with single polarization.

This corresponds to uncertainty of 22%.



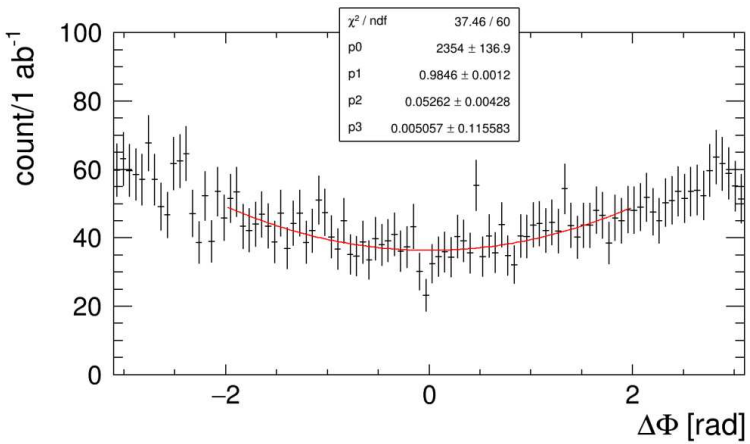


Analysis highlights

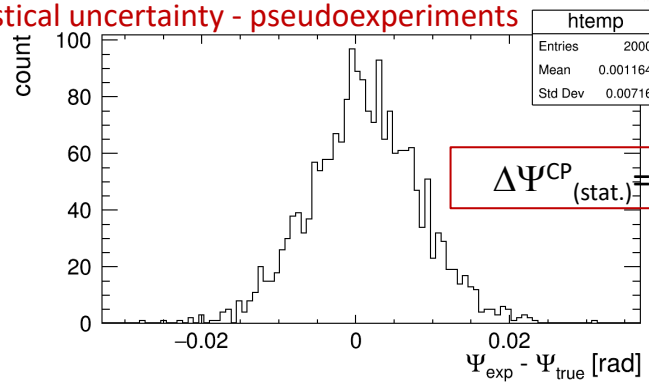
Probing CPV mixing in the Higgs sector at an e^+e^- collider at around 1 TeV,
N. Vukasinovic, I. Bozovic, G. Kacarevic

$\Delta\Phi$ reconstructed, corrected, local fit

Ψ_{CP}=0.0009 rad, $|\Psi_{true}-\Psi_{CP}|$ =0.9 mrad



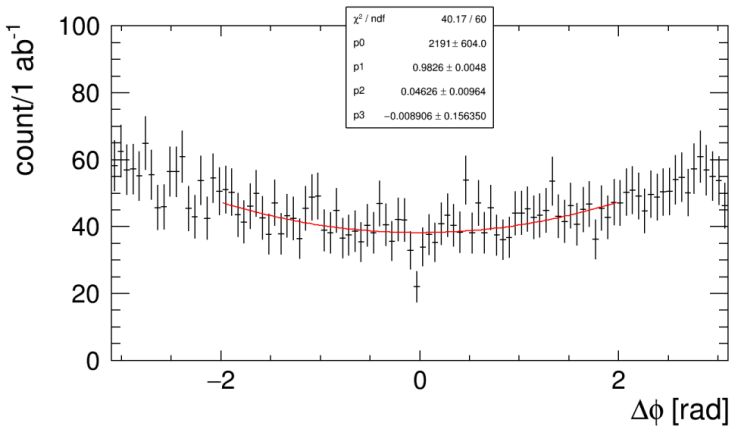
Statistical uncertainty - pseudoexperiments



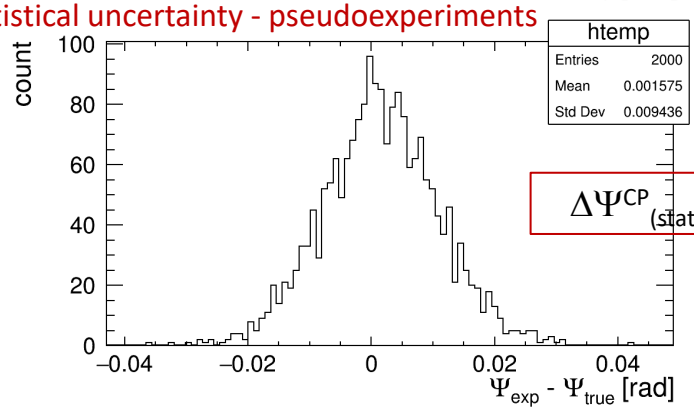
$\Delta\Psi^{CP}_{(stat.)}$ = 7 mrad

$\Delta\phi$ reconstructed, corrected, local fit

Ψ_{CP}=0.0016 mrad, $|\Psi_{true}-\Psi_{CP}|$ =1.6 mrad



Statistical uncertainty - pseudoexperiments

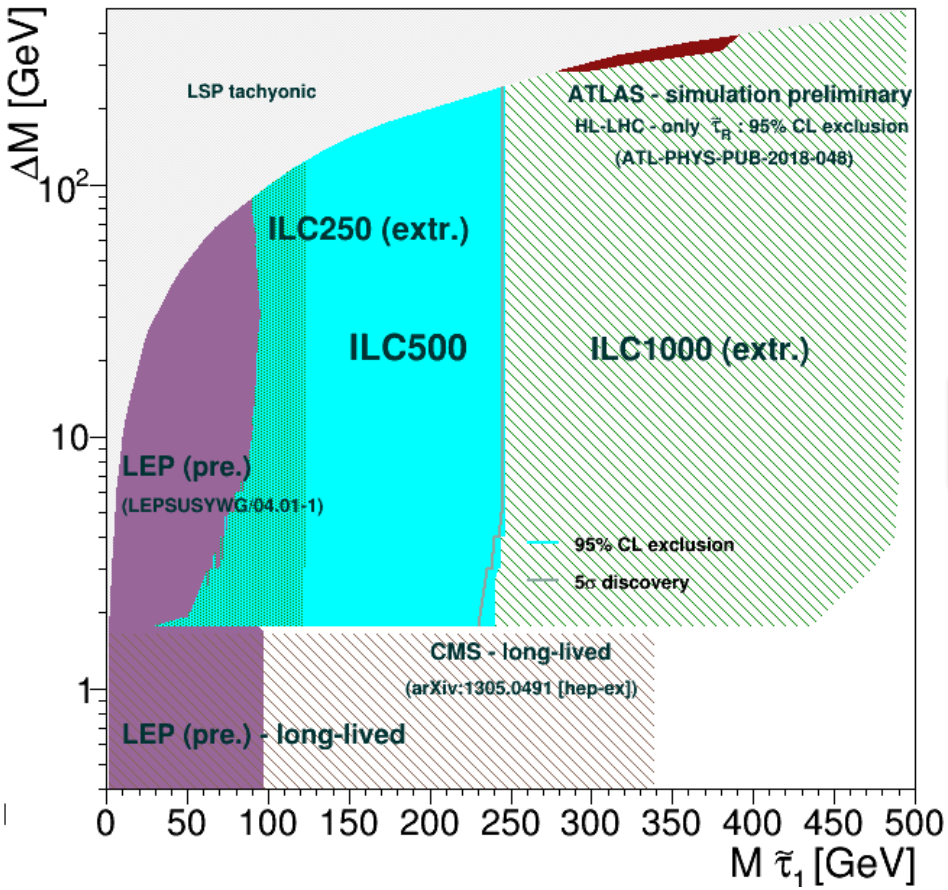


$\Delta\Psi^{CP}_{(stat.)}$ = 9 mrad

Analysis highlights

Evaluating the ILC SUSY reach in the most challenging scenario: $\tilde{\tau}$ NLSP, low ΔM , lowest cross-section, M.T. Núñez Pardo de Vera, M. Berggren, J. List, arXiv:2203.15729

Contribution to Snowmass 2021



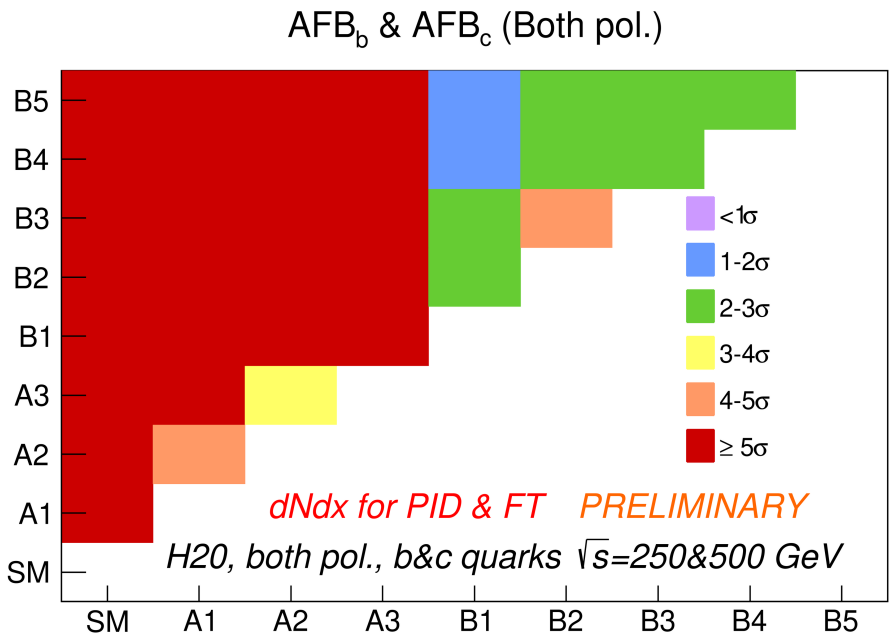
At ILC discovery and exclusion are almost the same

arXiv:2203.15729

Analysis highlights

Experimental prospects for indirect BSM searches in $e^+e^- \to q\bar{q}$, $q = c, b$ processes at ILC, Jesús P. Márquez Hernández

GHU's Models ILC250+500



*The 500 GeV results are an estimation using 2*syst. uncertainties & same preselection ef. than the 250 GeV case*

Accessing **higher energies** is a key factor to discriminate these models!

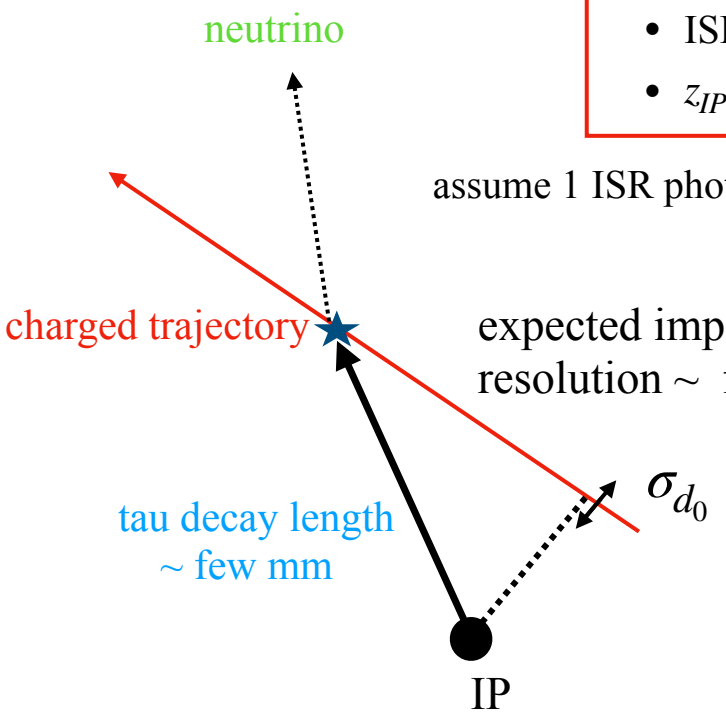
Analysis highlights

Measuring the tau polarisation at the ILC, Keita Yumino, Daniel Jeans

Unknown
- neutrino 3-momentum $\times 2$
- ISR momentum
- z_{IP}

Constraints
- 4-momentum conservation
- tau mass $\times 2$
- Decay point on trajectory $\times 2$

assume 1 ISR photon collinear with beam



expected impact parameter resolution ~ few um

For choice of z_{IP}, ϕ

we can calculate tau 4-momenta P_τ

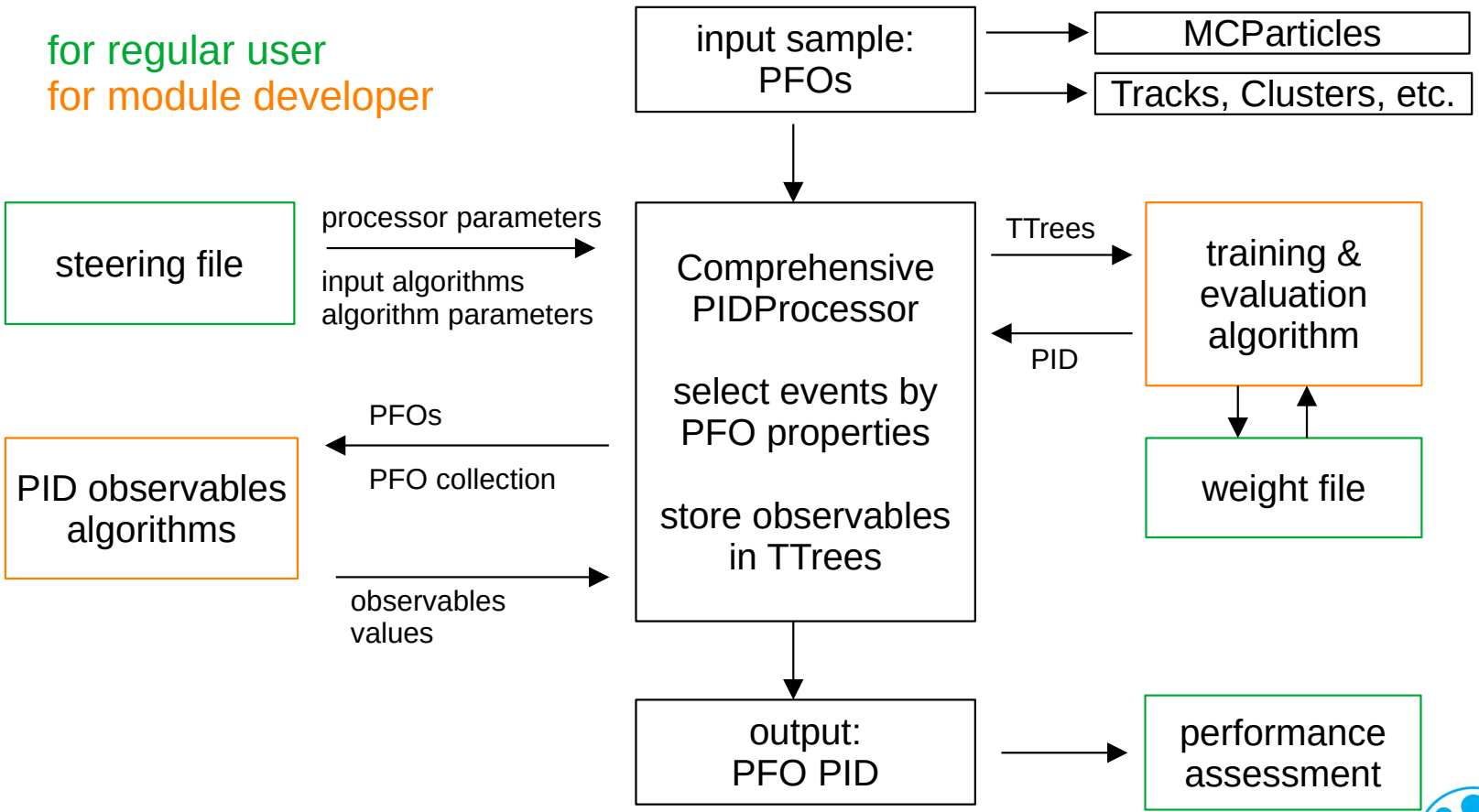
the invariant mass of the missing (neutrino) momentum for each tau can be calculated

$$P_\nu = P_\tau - P_{vis}$$

We choose the values of z and ϕ which result in neutrino masses closest to zero

Analysis highlights

Comprehensive Particle Identification Framework for Future e^+e^- Colliders, Uli Einhaus



LCWS'2023 contributions

links to indico contributions

Track 1

Physics at e^+e^- colliders, models of new physics, tests of the Standard Model through global fits

- CPV mixing in the Higgs sector at an e^+e^- collider at around 1 TeV center-of-mass energy (Natasa Vukasinovic)
- Higgs self-coupling measurement at ILC500 (Julie Munch Torndal)
- Stau searches at the ILC (Maria Teresa Nunez Pardo De Vera)
- RH neutrino pair-production at ILC (Jurina Nakajima)
- Prospects for light Higgs measurements at the 250 GeV ILC (Aleksander Filip Zarnecki)

LCWS'2023 contributions

links to indico contributions

Track 1

Physics at e^+e^- colliders, models of new physics, tests of the Standard Model through global fits

- CPV mixing in the Higgs sector at an e^+e^- collider at around 1 TeV center-of-mass energy (Natasa Vukasinovic)
- Higgs self-coupling measurement at ILC500 (Julie Munch Torndal)
- Stau searches at the ILC (Maria Teresa Nunez Pardo De Vera)
- RH neutrino pair-production at ILC (Jurina Nakajima)
- Prospects for light Higgs measurements at the 250 GeV ILC (Aleksander Filip Zarnecki)

Track 1 + 2

- Tuning Pythia8 for future e^+e^- colliders (Zhijie Zhao)
- Experimental prospects for indirect BSM searches in $e^+e^- \to q\bar{q}$, $q = c, b$ processes at ILC (Jesús P. Márquez Hernández)

LCWS'2023 contributions

Track 2

Analysis and reconstruction of e^+e^- processes, event simulation, precision calculation, physics performance

- A Particle Identification Framework for Linear Colliders (Ulrich Einhaus)
- Evaluating Detector and Physics Limitations on Center-of-Mass Energy Determination in e^+e^- Colliders Using Dileptons (Graham Wilson)
- High level reconstruction with DNN for Higgs factories (Taikan Suehara)
- Measuring tau polarisation at the ILC (Keita Yumino)
- Modeling Center-of-Mass Energy Precision using Dimuons and Bhabhas at ILC (Brendon Madison)
- Reconstruction of long-lived particles at the ILD (Jan Klamka)

ECFA Higgs/EW/Top factory study

see presentation by A.Robson for more details

Final report

Expected in 2025 (all inputs probably need to be finalized end 2024).
To be submitted as an input to the next European Strategy Update.
We need to make sure that our achievements are properly reflected...

ECFA Higgs/EW/Top factory study

see presentation by A.Robson for more details

Final report

Expected in 2025 (all inputs probably need to be finalized end 2024).
To be submitted as an input to the next European Strategy Update.
We need to make sure that our achievements are properly reflected...

Focus topics

Topics, that have not been covered in detail yet, interesting for all.
The goal is to encourage communication and collaboration between different projects, exchange expertise, attract new people...

We can also contribute to the identification and understanding of the FCC experimental challenges...

ECFA Focus topics

Proposed topics

1. **HtoSS** – $e^+e^- \to Zh$: $h \to ss$ ($\sqrt{s} = 240/250$ GeV)
2. **ZHang** – $e^+e^- \to Zh$: reconstruction of production and decay angles ($\sqrt{s} = 240/250$ GeV)
3. **Hself** – Determination of the Higgs self-coupling
4. **Wmass** – W mass from WW threshold and continuum ($\sqrt{s} = 161$ GeV)
5. **WWdiff** – Full studies of WW and $e\nu W$ ($\sqrt{s} = 240/250, 365$ GeV)
6. **TTthres** – Top threshold: Detector-level simulation study of $e^+e^- \to t\bar{t}$ at a typical threshold-scan energy ($\sqrt{s} = 350, 365$ GeV) and threshold scan optimisation
7. **LUMI** – Precision of the luminosity measurement from low-angle Bhabha scattering

Proposed topics (cont.)

8. **EXscalar** – New exotic scalars
9. **LLPs** – Long-lived particles
10. **EXtt** – Exotic top decays
11. **CKMWW** – CKM matrix elements with on-shell and boosted W decays at $\sqrt{s} \geq m_W$
12. **BKtautau** – $B^0 \to K^{0*}\tau^+\tau^-$
13. **TwoF** – EW precision: 2-fermion final states ($\sqrt{s} = M_Z$ and beyond)
14. **BCfrag** – Measurement of b- and c-fragmentation functions and hadronisation rates ($\sqrt{s} = M_Z$ and beyond)
15. **Gsplit** – Measurement of gluon splitting to bb / cc, interplay with separating $h \to$ gluons from $h \to bb/cc$ ($\sqrt{s} = M_Z$ and beyond)

ILD response

Contact persons appointed by ILD ⇒ members of the topical expert teams

#	topic	lead group	ILD group	ILD contact person
1	HtoSS	HTE	Higgs/EW	Taikan Suehara
2	ZHang	HTE (GLOB)	Higgs/EW	Ivanka Bozovic and Natasa Vukasinovic
3	Hself	GLOB	Higgs/EW	Junping Tian
4	Wmass	PREC	Higgs/EW	Graham Wilson
5	WWdiff	GLOB	Higgs/EW	Jenny List
6	TTdet	HTE	Top/HF/QCD	Marcel Vos
7	TTscan	GLOB (HTE)	Top/HF/QCD	Marcel Vos
8	LUMI	PREC	Higgs/EW	Ivanka Bozovic
9	EXscalar	SRCH	BSM	Mikael Berggren
10	LLPs	SRCH	BSM	Filip Zarnecki
11	EXtt	SRCH	BSM	—
12	CKMWW	FLAV	Top/HF/QCD	Uli Einhaus
13	BKtautau	FLAV	Top/HF/QCD	—
14	TwoF	HTE	Top/HF/QCD	Adrian Irles and Roman Pöschl
15	BCfrag	FLAV (PREC)	Top/HF/QCD	Adrian Irles
16	Gsplit	PREC (FLAV)	Higgs/EW	(same expert team as 15?)

Interested ILD members are encouraged to join the effort...

Analysis priorities

There are still a lot of open physics problems to be addressed within ILD
Examples of interesting topics, which wait for volunteers are given below.
Many thanks to Junping Tian and Ivanka Bozovic for compiling this list

Analysis priorities

There are still a lot of open physics problems to be addressed within ILD
Examples of interesting topics, which wait for volunteers are given below.
Many thanks to Junping Tian and Ivanka Bozovic for compiling this list

Uncovered subjects

Exotic decays ($H \to \phi\phi \to \dots$)
Reinforce study on Higgs exotic decays, in particular in relation to DM;

Also to be extended to searches/identification of new exotic scalars

Flavorful Higgs decays
$H \to sb$ flavor violation models, but also $H \to ss$ for s-quark Yukawa coupling, with improved s-tag algorithm;

Analysis priorities

Possible new developments in previously completed studies

Higgs BRs measurements

$H \to bb(cc, gg)$ with improved flavor tagging algorithms,
combined analysis of different channels

Higgs recoil mass

Better understating of systematic uncertainties,
in particular in primary Z hadronic decays;

Consider hadronic Z decay channel also in new scalar search

Anomalous TGCs

Explore the potential of constraining CP-odd aTGCs;
Understand interplay between aTGCs and other Higgs/EW measurements;

Analysis priorities

Possible advances in ongoing studies

Higgs self-coupling

Combining di-Higgs and single Higgs production measurements
for more clear picture and better understating of theoretical interpretations

CPV in Higgs decays

Better tau and tau polarization reconstruction,
common interpretation for Hff and HVV vertices;

Indirect BSM searches

Explore more EWPOs, other than A_{LR}, and better understand systematics;

Conclusions

Convincing physics case for has already been presented for ILC
But we should still work to strengthen it, explore new scenarios, understand all details...

Conclusions

Convincing physics case for has already been presented for ILC
But we should still work to strengthen it, explore new scenarios, understand all details...

ILD detector was designed to make full use of the ILC physics potential
However, new technology options, new possibilities appear (eg. timing), which should be considered, design has to evolve...

Conclusions

Convincing physics case for has already been presented for ILC
But we should still work to strengthen it, explore new scenarios, understand all details...

ILD detector was designed to make full use of the ILC physics potential
However, new technology options, new possibilities appear (eg. timing), which should be considered, design has to evolve...

ILD was proposed as a mature detector concept for the ILC
We need to demonstrate it is applicable to other Higgs Factory options...

Conclusions

Convincing physics case for has already been presented for ILC
But we should still work to strengthen it, explore new scenarios, understand all details...

ILD detector was designed to make full use of the ILC physics potential
However, new technology options, new possibilities appear (eg. timing), which should be considered, design has to evolve...

ILD was proposed as a mature detector concept for the ILC
We need to demonstrate it is applicable to other Higgs Factory options...

If you want to get involved, please contact us:

ild-physics-conveners@desy.de