

Summary talk (BSM)

Conveners: *M. Berggren (DESY), S. Matsumoto (IPMU),
W. Porod (Wurzburg U.), S. P. Griso (LBNL).*

Relevant sessions: *BSM sessions (H-1, H-2, H-3 sessions)
Higgs & BSM session (F&H-1, F&H-2 ")
BSM & FT session (H&O ")*

These sessions discussed new particle productions at lepton colliders!

Topics discussed:

- ✓ *Searching extend Higgs sectors at future lepton colliders.*
- ✓ *Searching dark matters at future lepton colliders (FLCs).*
- ✓ *Searching Supersymmetry at FLCs.*
- ✓ *Searching long-lived particles at FLCs. ← Already previewed!*
- ✓ *Searching the origin of neutrino masses at FLCs.*
- ✓ *Developments on BSM signal detections at FLCs.*

Searching extend Higgs sectors at FLCs

Searching for Charged via $e^+e^- \rightarrow H^+ H^- \rightarrow b\bar{c}bc\bar{c}$ at Linear colliders

We present a search for the charged Higgs boson via $e^+e^- \rightarrow H^+ H^- \rightarrow b\bar{c}bc\bar{c}$ at the 500 GeV ILC. In a general two Higgs doublet model without $SU(2)_C$ symmetry, extra Yukawa couplings such as $\lambda_{rb} \bar{t}c$ and $\lambda_{rb} \bar{t}b$ can arise phenomenologically. But searching for the CP

🕒 10:00 AM - 10:20 AM
📍 Room #2 (Zoom Meeting ID: 823 6921 2312)

Presenter Rishabh Jain

Electroweak Baryogenesis in Higgs aligned 2HDM and its prediction at the ILC

The scenario of electroweak baryogenesis in the CP violating extended Higgs model has been strongly limited by current EDM experiments, hence it is difficult to generate the observed baryon density in our universe.

🕒 10:40 AM - 11:00 AM
📍 Room #2 (Zoom Meeting ID: 823 6921 2312)

Presenter Yushi Mura

Analyzing the Higgs potential in gauge-Higgs unification with a flat extra dimension

We investigate the structure of the Higgs potential in gauge-Higgs unification with a flat extra dimension. As a viable gauge-Higgs unification model, we take the one where the Standard Model Higgs doublet is embedded into a higher-dimensional gauge field.

🕒 11:00 AM - 11:20 AM
📍 Room #2 (Zoom Meeting ID: 823 6921 2312)

Presenter Mitsuru Kakizaki

Imprint of quark flavor violating SUSY in $h(125)$ decays at ILC

We study the Higgs boson decays $h \rightarrow c\bar{c}, b\bar{b}, b\bar{s}, \text{photon photon}$ and gluon gluon in the Minimal Supersymmetric Standard Model (MSSM) with general quark flavor violation (QFV), identifying the h with the Higgs boson.

🕒 11:20 AM - 11:40 AM
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Presenter Keisho HIDAKA

A model for tiny neutrino masses, dark matter, and baryon asymmetry and its phenomenology at the ILC

The origin of tiny neutrino masses, dark matter, and baryon asymmetry of the universe is still a mystery, and there is no doubt that there is new physics beyond the Standard Model. In a previous work, a new physics model at TeV scale, which can explain the origin of neutrino

🕒 1:40 PM - 2:00 PM
📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

Presenters Kazuki Enomoto

The THDMa and possible e^+e^- signatures

The THDMa is a new physics model that extends the scalar sector of the Standard Model by an additional doublet as well as a pseudoscalar singlet and allows for mixing between all possible scalar states. In the gauge

🕒 7:00 PM - 7:20 PM
📍 Room #2 (Zoom Meeting ID: 823 6921 2312)

Presenter Tania Natalie Robens

Impact of overlay events on the charged IDM scalar reconstruction at CLIC

The Inert Doublet Model (IDM) is one of the simplest SM extensions and introduces four new scalar particles: H^{\pm}, A and H , the lightest, H , is stable and hence it is a natural dark matter (DM) candidate. A set of benchmark points is considered, which are consistent with

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Presenter Jan Klamka

Sizable triple Higgs couplings in the 2HDM: Prospects for future e^+e^- colliders

We analyze the possible size of various triple Higgs couplings in the 2HDM (type I and II), allowed by all current theoretical and experimental constraints. We discuss how one can get access to them at future e^+e^- colliders.

🕒 7:40 PM - 8:00 PM
📍 Room #2 (Zoom Meeting ID: 823 6921 2312)

Presenter Francisco Arco

Off diagonal charged scalar couplings with the Z boson

Models with scalar doublets and charged scalar singlets have the interesting property that they have couplings between one Z boson and two charged scalars of different masses. This property is often ignored in phenomenological studies.

🕒 8:00 PM - 8:20 PM
📍 Room #2 (Zoom Meeting ID: 823 6921 2312)

Presenter Ricardo Florentino

A 96 GeV Higgs Boson in the 2HDMs and the N2HDM

We analyze the possible realization of a 96 GeV Higgs boson describing the "excesses" observed at CMS in the di-photon decay channel and at LEP in the $S_b \rightarrow b\bar{b}$ decay channel. We compare the realizations in the

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Presenter Cheng Li

Global Interpretation of LHC indications within the GM model

LHC has produced several indications for new scalars. This talk intends to interpret them within the Georgi Machacek scheme and predict their cross section at ILCWS21 and attempts to complete

🕒 8:00 PM - 8:20 PM
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Presenter Francois Richard

Influence of dark matter spin on detection possibility at future e^+e^- colliders

It is commonly believed that Dark Matter (DM) should exist in the form of new, Beyond-the-Standard-Model stable particles.

🕒 8:40 PM - 9:00 PM
📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

Presenter Michal Iglicki

Various extend Higgs sectors (2HDM, 2HDMa, IDM, N2HDM, GM, ...) were discussed based on

- ✓ **Baryon Asymmetry of Universe via EWBG.**
- ✓ **TeV scale BSM (SUSY, GHU, CompH, etc.).**
- ✓ **Dark matter problem (Higgs portal, etc.).**
- ✓ **Ex. anomalies (98GeV Higgs, LHC ones, ...).**

Searching extend Higgs sectors at FLCs

Talk by K. Hidaka @ the F&H-1 session.

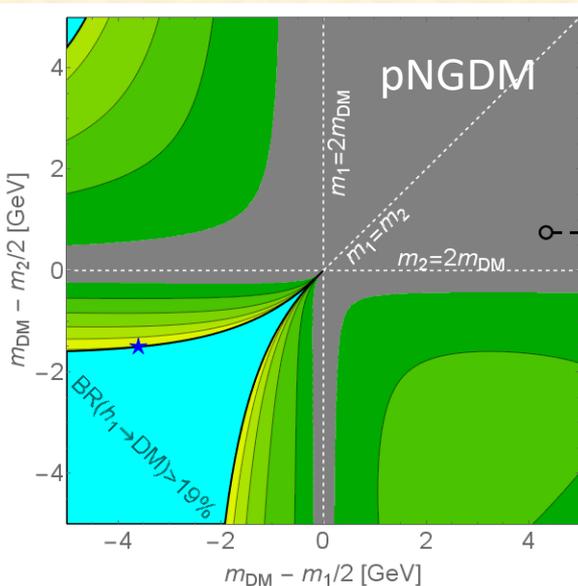
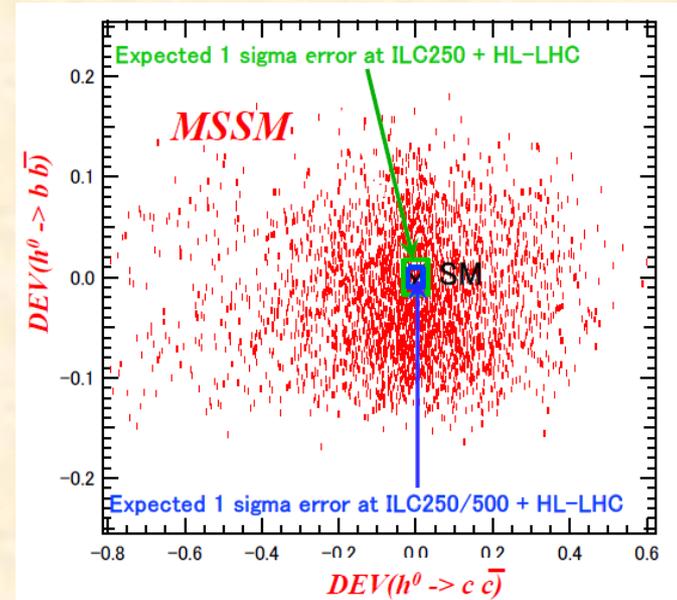
Scanning MSSM with QFV by imposing various constraints (Various LHC limits, B/K data, EWPM, Vacuum stability, ...) shows that the deviations on decay widths from SM predictions could be

$DEV(h^0 \rightarrow c \bar{c})$ can be as large as $\sim \pm 60\%$.

$DEV(h^0 \rightarrow b \bar{b})$ can be as large as $\sim \pm 20\%$.

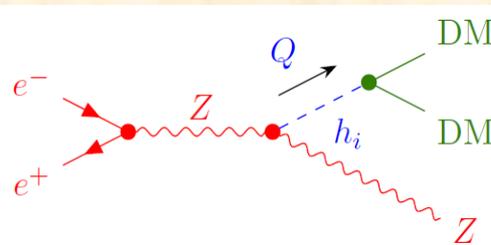
Moreover,

$BR(h^0 \rightarrow b \bar{s} / s \bar{b})$ can be as large as $\sim 0.17\%$



Talk by M. Iglicki @ the H-3 session.

Higgs portal: SM - Singlet Scalar Mediator - DM



BG: $e^-e^+ \rightarrow ZZ \rightarrow Z\nu\nu$

$\sigma(\text{pGDM}) / \sigma_{\text{SM}}$

0.05 0.10 0.15 0.20 0.25



\uparrow
(pNGDM, FDM, VDM)

Mono-Z search works for all the cases even at 250GeV ILC.

Cases of different spins can be disentangled in some regions.

Searching dark matters at FLCs.

Impact of light dark matter on Higgs physics

We explore a novel possibility that dark matter has a light mass below 1 GeV in a lepton portal dark matter model. There are Yukawa couplings involving dark matter, left-handed leptons and an extra scalar doublet in the model. In the light mass region, dark matter is thermally produced.

🕒 10:20 AM - 10:40 AM

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👤 Presenter Yuji Omura

A model for tiny neutrino masses, dark matter, and baryon asymmetry and its phenomenology at the ILC

The origin of tiny neutrino masses, dark matter, and baryon asymmetry of the universe is still a mystery, and there is no doubt that there is new physics beyond the Standard Model. In a previous work, a new physics model of TeV-scale origin of all fermion and gauge boson

🕒 1:40 PM - 2:00 PM

📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

👤 Presenters Kazuki Enomoto

Searching for Lepton Portal Dark Matter at Linear Colliders

In this talk, I discuss the phenomenology of a minimal model for GeV-scale Majorana dark matter (DM) coupled to the standard model lepton sector via a charged scalar singlet. The theoretical framework extends the Standard Model by two SU(2)_L singlets, one charged

🕒 2:00 PM - 2:20 PM

📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

👤 Presenter Adil Jueid

The search for leptophilic WIMP at ILC

We consider the renormalizable leptophilic WIMP models with the scalar mediators which have lepton numbers. We perform a comprehensive analysis for such a WIMP scenario for two distinct cases with SU(2)

🕒 2:20 PM - 2:40 PM

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👤 Presenter Taisuke Katayose

Dark Matter and Collider Searches at ILC in $S_{\bar{S}} S_3$ -Symmetric 2HDM with Vector Like Leptons

We study the $S_{\bar{S}} S_3$ -symmetric two Higgs doublet model by adding two generations of vector like leptons (VLL) which are odd under a discrete $S_{\bar{Z}} S_2$ -symmetry. The lightest neutral component of the VLL acts as a dark matter

🕒 3:50 PM - 4:10 PM

📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

👤 Presenter Nivedita Ghosh

Quest for Dark Matter at International Linear Collider

Future accelerators like ILC or CLIC are with immense possibilities to improve our understanding of nature's fundamental building blocks and to discover new particles, e.g., WIMPs along with other physics phenomena. In

🕒 4:10 PM - 4:30 PM

📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

👤 Presenters Atanu Guha
Saumyen Kundu

The THDMa and possible e^+e^- signatures

The THDMa is a new physics model that extends the scalar sector of the Standard Model by an additional doublet as well as a pseudoscalar singlet and allows for mixing between all possible scalar states. In the gauge

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👤 Presenter Jan Klamka

Influence of dark matter spin on detection possibility at future e^+e^- colliders

It is commonly believed that Dark Matter (DM) should exist in the form of new, Beyond-the-Standard-Model stable particles.

Despite continued efforts, such particles have not yet been detected, which means that

🕒 8:40 PM - 9:00 PM

📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

👤 Presenter Michał Iglicki

Radiative Neutrino Mass with GeV Scale Majorana Dark Matter in Scotogenic Model

The experimental observations from the colliders established the standard model (SM), the most successful phenomenological framework to explain the non-gravitational interactions of fundamental particles at high energies. Majorana dark matter is produced

🕒 8:20 PM - 8:40 PM

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👤 Presenters Avnish
Kirtiman Ghosh

In addition to DM scenarios in the framework of extended H sectors [Talks by K. Enomoto, T. Robens, J. Klamka, M. Iglicki, Avnish], there are also many presentations of the so-called leptophilic DM coupling mainly to SM leptons.

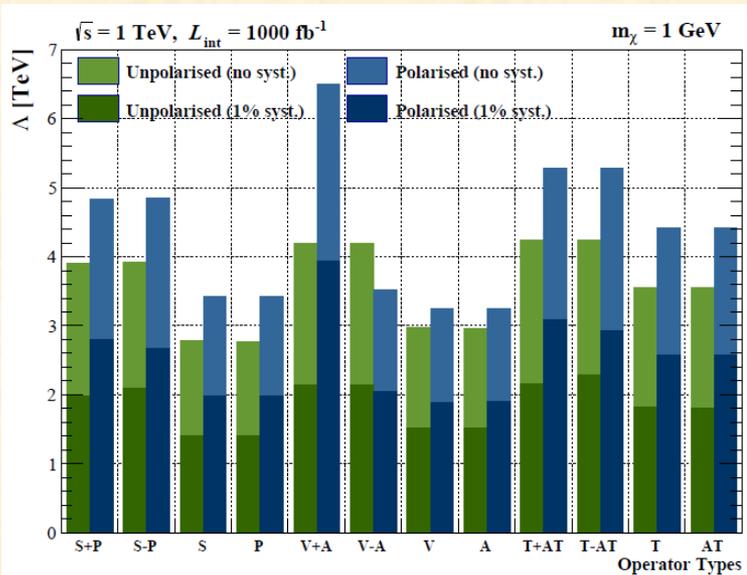
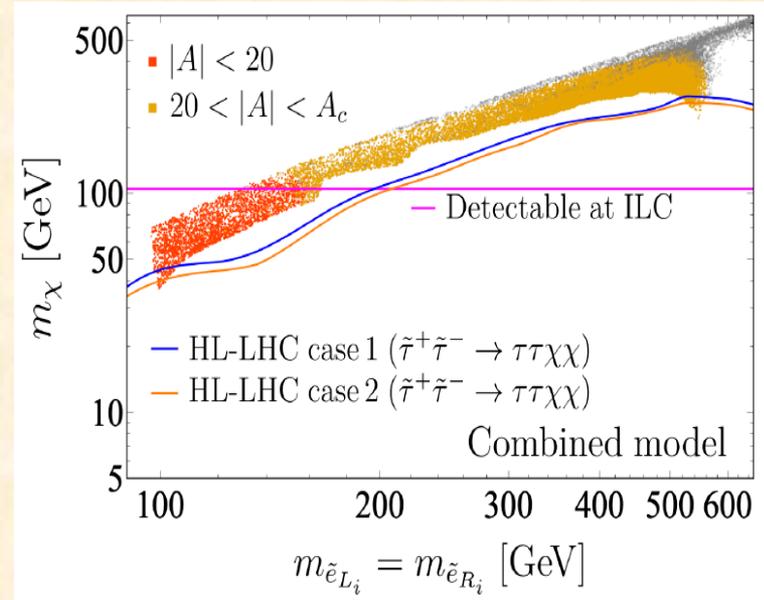
- ✓ ***The leptophilic DM is not sensitive to direct detection /LHC experiments.***
- ✓ ***Very light DM mass region of $O(1)$ GeV is surviving [Talk by Y. Omura].***
- ✓ ***The DM can be tested at FLCs via mono-X searches [Talk by A. Jueid].***
- ✓ ***The DM can be embedded in extended H sectors [Talk by N. Ghosh].***

Searching dark matters at FLCs.

Talk by T. Katayose @ the H-1 session.

Scanning of a leptophilic model by imposing constraints (various LHC limits, EWPM, relic abundance, etc.) shows that a low DM mass region (below 100GeV) is still surviving.

- ✓ *Mono- γ search works even at 250GeV ILC.*
- ✓ *It can accommodate with “ $g_\mu - 2$ anomaly”.*
- ✓ *Leptophilic DM can be realized in MSSM, via Bino-slepton coannihilation scenario.*



Talk by S. Kundu @ the H-2 session.

When the mediator particle is heavy enough and center of mass energy at FLCs is also large enough, we can develop the ILC study of the leptophilic DM using the EFT method.

$$\mathcal{L}_{\text{eff}} = \frac{1}{\Lambda^2} \sum_j (\bar{\chi} \Gamma_\chi^j \chi) (\bar{\ell} \Gamma_\ell^j \ell)$$

Multi-TeV scale can be explored at 1TeV ILC!

Searching Supersymmetry at FLCs.

<h3>Imprint of quark flavor violating SUSY in $h(125)$ decays at ILC</h3> <p>We study the Higgs boson decays $h \rightarrow c\bar{c}, b\bar{b}, b\bar{s}, \text{photon photon}$ and gluon gluon in the Minimal Supersymmetric Standard Model (MSSM) with general quark flavor violation (QFV), identifying the h with the Higgs boson</p> <p>🕒 11:20 AM - 11:40 AM 📍 Room #2 (Zoom Meeting ID: 823 6921 2312)</p> <p>Presenter Keisho HIDAKA</p>	<h3>New muon $(g-2)$ result and ILC as target for Supersymmetry</h3> <p>We confront the Minimal Supersymmetric Standard Model (MSSM) with the recent measurement of $(g-2)_\mu$, the Dark Matter (DM) relic density, DM direct detection limits and electroweak SUSY searches at the LHC. We</p> <p>🕒 4:50 PM - 5:10 PM 📍 Room #4 (Zoom Meeting ID: 840 3553 0145)</p> <p>Presenter Ipsita Saha</p>	<h3>Measuring neutrino physics through light higgsinos and sneutrinos</h3> <p>If nature is supersymmetric and not fine-tuned, higgsinos may well be within the reach of the ILC. In the NMSSM extended with right-handed neutrinos the right-handed sneutrino is a viable thermal dark matter candidate. We discuss how</p> <p>🕒 5:10 PM - 5:30 PM 📍 Room #4 (Zoom Meeting ID: 840 3553 0145)</p> <p>Presenter Harri Waltari</p>	<h3>Stau Searches at the ILC</h3> <p>"The direct pair-production of the tau-lepton superpartner, stau, is one of the most interesting channels to search for SUSY. First of all the stau is with high probability the lightest of the scalar leptons. Secondly the</p> <p>🕒 7:20 PM - 7:40 PM 📍 Room #4 (Zoom Meeting ID: 840 3553 0145)</p> <p>Presenters Maria Teresa Nunez Pardo de Vera</p>	<h3>Flavour Non-Universal UMSSM at the Linear Colliders</h3> <p>We studied phenomenological implications of numerous Family Non-Universal $U(1)'$ sub-models in the minimal $U(1)'$ extended Supersymmetric Model (UMSSM) possessing an extra down quark type exotic field. In doing this, we started with anomaly cancellation</p> <p>🕒 7:40 PM - 8:00 PM 📍 Room #4 (Zoom Meeting ID: 840 3553 0145)</p> <p>Presenter Yasar Hicyilmaz</p>
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There are also several presentations about the search for Supersymmetry!

Some of them are discussed based on

- ✓ **Experimental indications** (ν mass [Talk by H. Waltari], $g_\mu - 2$.)
- ✓ **Theoretical motivation** (μ -problem [Talk by Y. Hicyilmaz.])
- ✓ **Experimental viewpoints** (stau NLSP, QFV.)

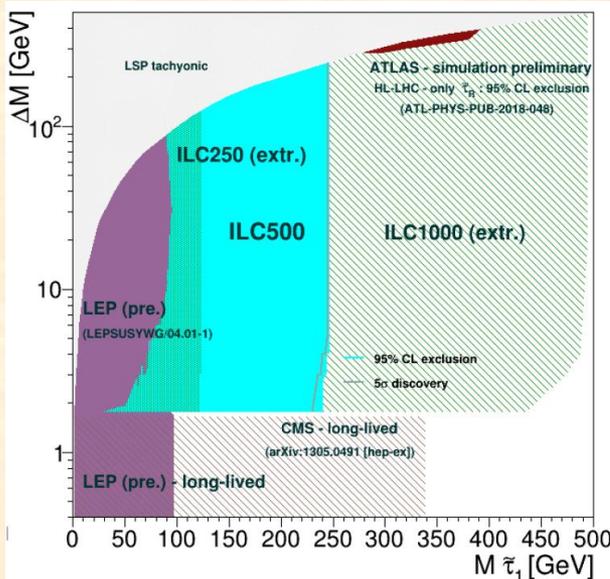
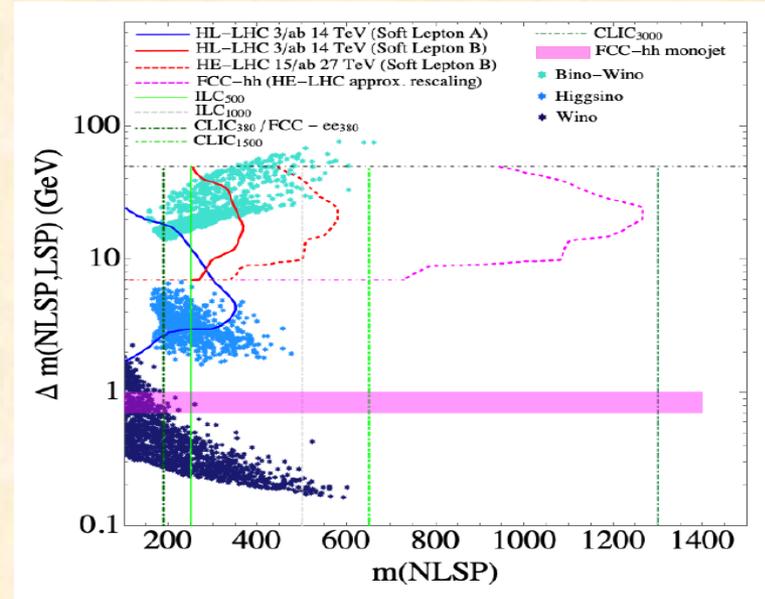
Searching Supersymmetry at FLCs.

Talk by I. Saha @ the H-2 session.

Scanning of MSSM by imposing constraints, various properly recast LHC limits, EWPM, relic abundance (upper limit), direct dark matter detection, as well as $g_\mu - 2$ indication, give us the finite mass region of sparticles.

- ✓ Upper limit is from the $g_\mu - 2$ indication.*
- ✓ Lower limit is from proper LHC limits.*

Implication to FLCs (ILC) is now under study!



Talk by M. T. Nunez Pardo de Vera @ H-3 session.

Stau NLP scenario is well-motivated but known to be one of the most difficult ones in the MSSM.

It is presented here that ILC will discover/exclude status for any stau-LSP mass difference as well as any stau mixing nearly up to kinematic limit.

Moreover,

Stau parameters measurement were also discussed.

Searching the origin of neutrino masses at FLCs.

Testing the neutrino mass generation mechanism at the electron positron colliders

The neutrinos have tiny mass which is not predicted in the Standard Model. Therefore the extension of the SM is unavoidable. A plethora of scenarios have been proposed to explain the origin of the tiny neutrino mass which include the $\nu\nu$ Majorana mass and gauge extensions.

🕒 1:00 PM - 1:20 PM
📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

Presenter Arindam Das

Exploring Right Handed Neutrinos at ILC

We study search for Right Handed Neutrino at ILC. The process we focus on is the Z' boson mediated Right Handed neutrino (RHN) pair production process. The advantage of RHN pair production process is back ground free process.

In final state, RHN pair production shows the

🕒 1:20 PM - 1:40 PM
📍 Room #4 (Zoom Meeting ID: 840 3553 0145)

Presenter Jurina Nakajima

A model for tiny neutrino masses, dark matter, and baryon asymmetry and its phenomenology at the ILC

The origin of tiny neutrino masses, dark matter, and baryon asymmetry of the universe is still a mystery, and there is no doubt that there is new physics beyond the Standard Model. In a previous work, a new physics model at TeV scale is proposed.

🕒 1:40 PM - 2:00 PM
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Presenters Kazuki Enomoto

Probing the minimal $U(1)_{X'}$ model at future electron-positron collider via fermion pair production

The minimal $U(1)_{X'}$ extension of the Standard Model (SM) is a well-motivated new physics scenario, where the anomaly cancellation requirement dictates the new neutral gauge boson $Z'(\nu)$ couplings.

🕒 4:30 PM - 4:50 PM
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Presenter Arindam Das

Radiative Neutrino Mass with GeV Scale Majorana Dark Matter in Scotogenic Model

The experimental observations from the colliders established the standard model (SM), the most successful phenomenological framework to explain the non-gravitational interactions of fundamental particles at high energy.

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Presenters Avnish Kirtiman Ghosh

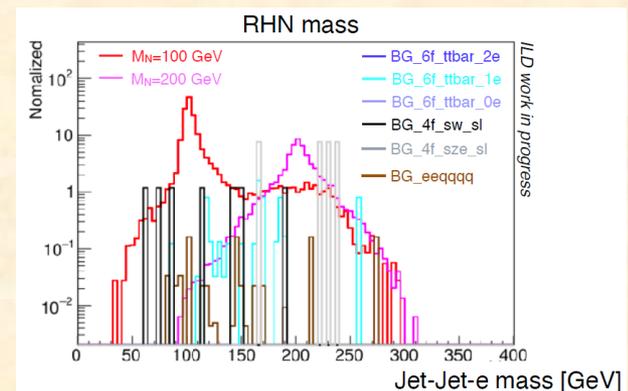
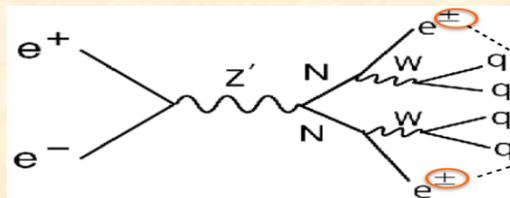
The origin of the neutrino masses may not be at very high energy scale. If its origin is at around the TeV scale, FLCs could have an opportunity to reveal it!

Such a possibility was theoretically discussed in the framework of

- ✓ *Type I, II, III seesaw scenarios by A. Das in the H-1 session.*
- ✓ *Radiative seesaw scenario by K. Enomoto in the H-1 session.*
- ✓ *$U(1)$ extension of the standard model by A. Das in the H-2 session.*
- ✓ *Scotogenic model by Avnish in the H-3 session.*

Moreover, a full simulation on such study has also began. [Talk by J. Nakajima in the session H-1.]

The same sign lepton signal:



Developments on BSM signal detections at FLCs,

Probing heavy charged fermions at e^+e^-S collider using the Optimal Observable Technique

In this work, we study the production of color-neutral and singly-charged heavy leptons at the proposed International Linear Collider. We use the optimal observable technique to determine the statistical accuracy to which the coupling of

3:30 PM - 3:50 PM
Room #4 (Zoom Meeting ID: 840 3553 0145)

Presenter Sahabub Jahedi

Talk by S. Jahedi at the H-2 session,

Optimal observable technique is applied to heavy fermion prod. via Z-boson exchange in the s-channel at FLCs, and discuss how accurately the Z-F-F vertex structure can be determined.

Talk by Julia Lynne Gonski at the H-3 session,

Machine learning methods based on semisupervised and weakly supervised learning can achieve model-independent sensitivity to the production of new particles in radiative return events.

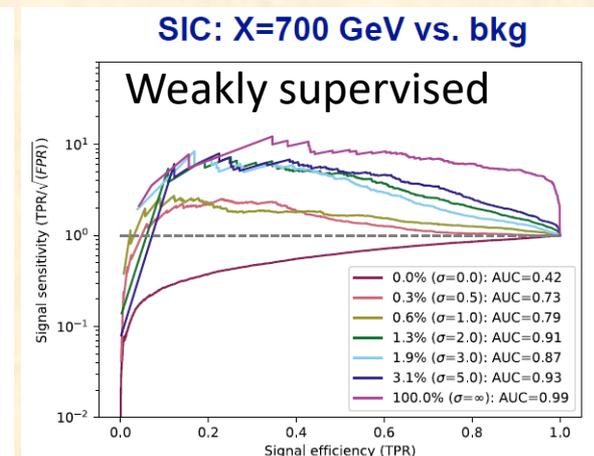
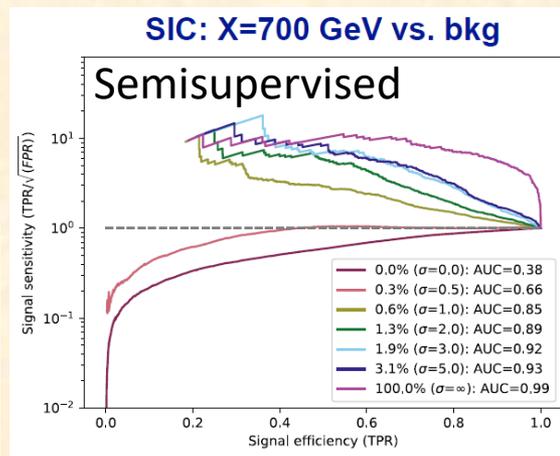
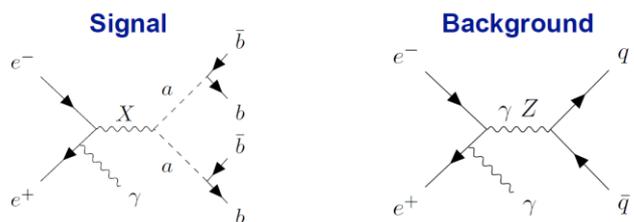
High-dimensional Anomaly Detection with Radiative Return in e^+e^- Collisions

Experiments at a future e^+e^- collider will be able to search for new particles with masses below the nominal centre-of-mass energy by analyzing collisions with initial-state radiation (radiative return). We show that machine

7:00 PM - 7:20 PM
Room #4 (Zoom Meeting ID: 840 3553 0145)

Presenter Julia Lynne Gonski

Qualitative discussion using the concrete example:



Concluding remarks

We had many presentations on (on-shell) new particle productions at future lepton colliders. Concrete topics discussed at ILCX2021 are

- ✓ *Searching extend Higgs sectors at future lepton colliders.*
- ✓ *Searching dark matters at future lepton colliders (FLCs).*
- ✓ *Searching Supersymmetry at FLCs.*
- ✓ *Searching long-lived particles at FLCs.*
- ✓ *Searching the origin of neutrino masses at FLCs.*
- ✓ *Developments on BSM signal detections at FLCs.*

Very interestingly, almost all the topics presented in the sessions are motivations by experimental BSM signals/anomalies/indications that can not be described within the framework of the standard model, (i. e. dark matter, neutrino masses, $g_{\mu}-2$, B anomalies, 98GeV higgs, etc.).

Moreover, the possibility of new options, such as beam dump facilities, dedicated LLP detectors, new intense photon source, $\gamma\gamma$ collision, etc. makes the scope/range of BSM discussions significantly enlarged!