Status of LLP Studies at Future Electron Positron Colliders

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OUTLINE

LLP Searches @ ee Colliders

Studies with Near Detectors

Studies with Far Detectors

Studies with beam dump

Discussion & Advertisement

Please feel free to contact me (kechen.wang@whut.edu.cn) if your studies are missed !

Theory Motivation

LLP: Relatively long lifetime or equivalently decay length

New particles become long-lived because of:
→ feeble couplings to SM particles
→ phase space suppression
→ approximate symmetry
→ heavy mediators, ...

The discovery of LLPs could explain some fundamental problems:
neutrino mass, dark matter, baryogenesis, naturalness, ...

LLP searches are important ways to BSM physics.

Idea of LLP searches @ colliders

When a LLP produced at 0 (usually the IP),

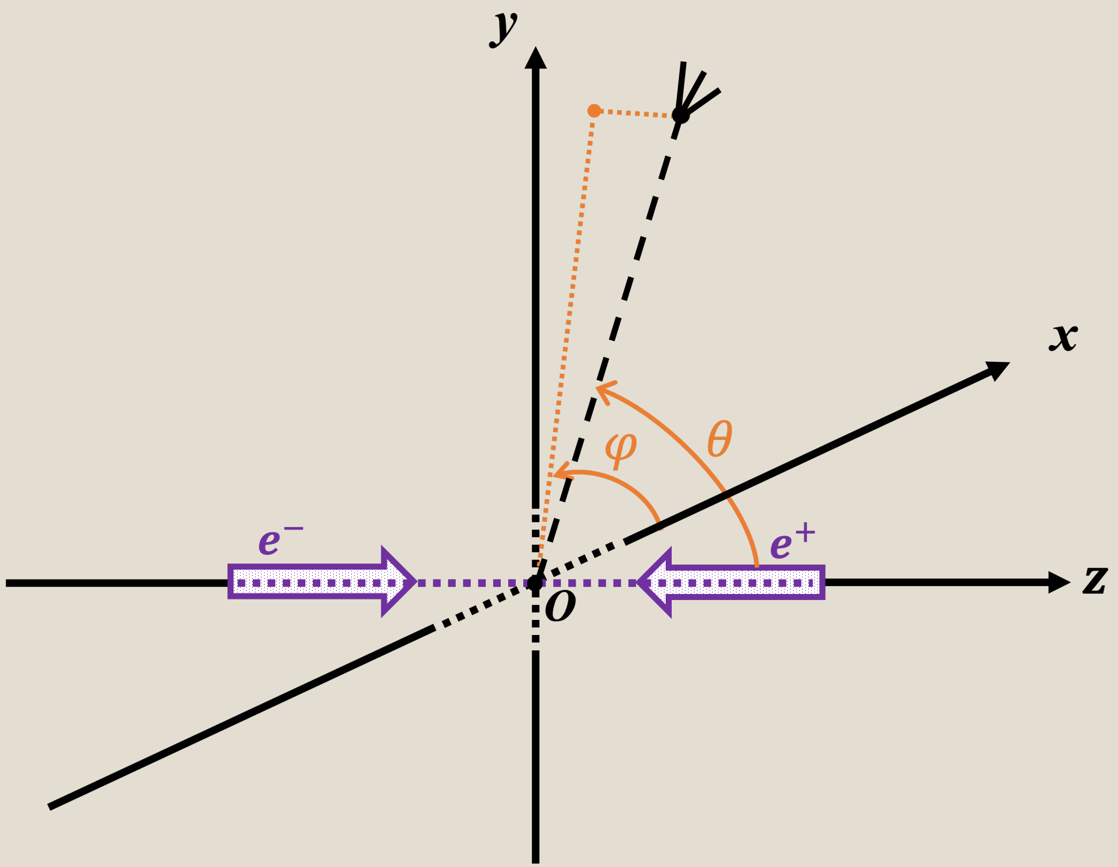
Probability of still existing (does not decay) at L

$$P(L) = e^{-L/\lambda}$$

where decay length in the lab. frame

$$\lambda = \beta\gamma\, c\tau = \left(\frac{p}{m}\right) (c\tau)$$

Kinematics lifetime in the rest frame



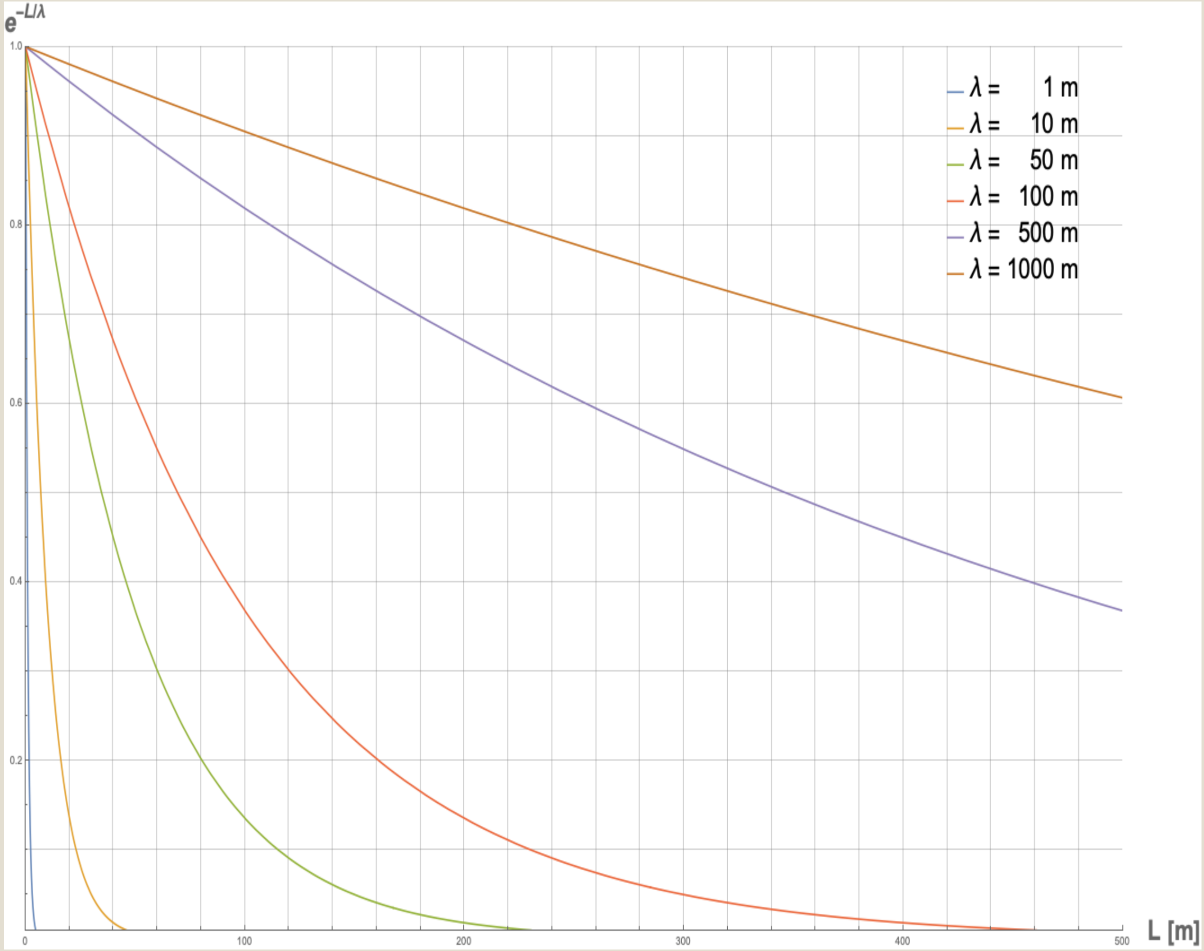
Idea of LLP searches @ colliders

Probability of decaying between L_1 and L_2 ($L_1 < L_2$)

$$P(\Delta L) = e^{-L_1/\lambda} - e^{-L_2/\lambda}$$

L_1 and L_2 :
determined by the detector (position, shape, volume, ...) & LLP's moving direction

Exponential Decay



Idea of LLP searches @ colliders

$$N_{\mathrm{exp}} = N_{\mathrm{pro}} \cdot P \cdot \mathrm{Br} \cdot \epsilon$$

# of LLPs produced

probability of decaying inside the detector's fiducial volume

Branching ratio of LLP decaying into visible final state

detector efficiency

expected # of signal events:
depends on theory model parameters (mass, lifetime, kinematics) & geometry and performance of detector (position, shape, volume, efficiency)

@ *ee* vs. *pp*
***ee*:** high lum., clean environment, EW prod., transverse direction, recoil strategy
***pp*:** forward direction

Signatures of LLPs in ND

When $\lambda \sim \mathcal{O}(1)$ m,

Mainly decay inside the near detector

Appear as displaced vertex

Various final states depending on different decay products

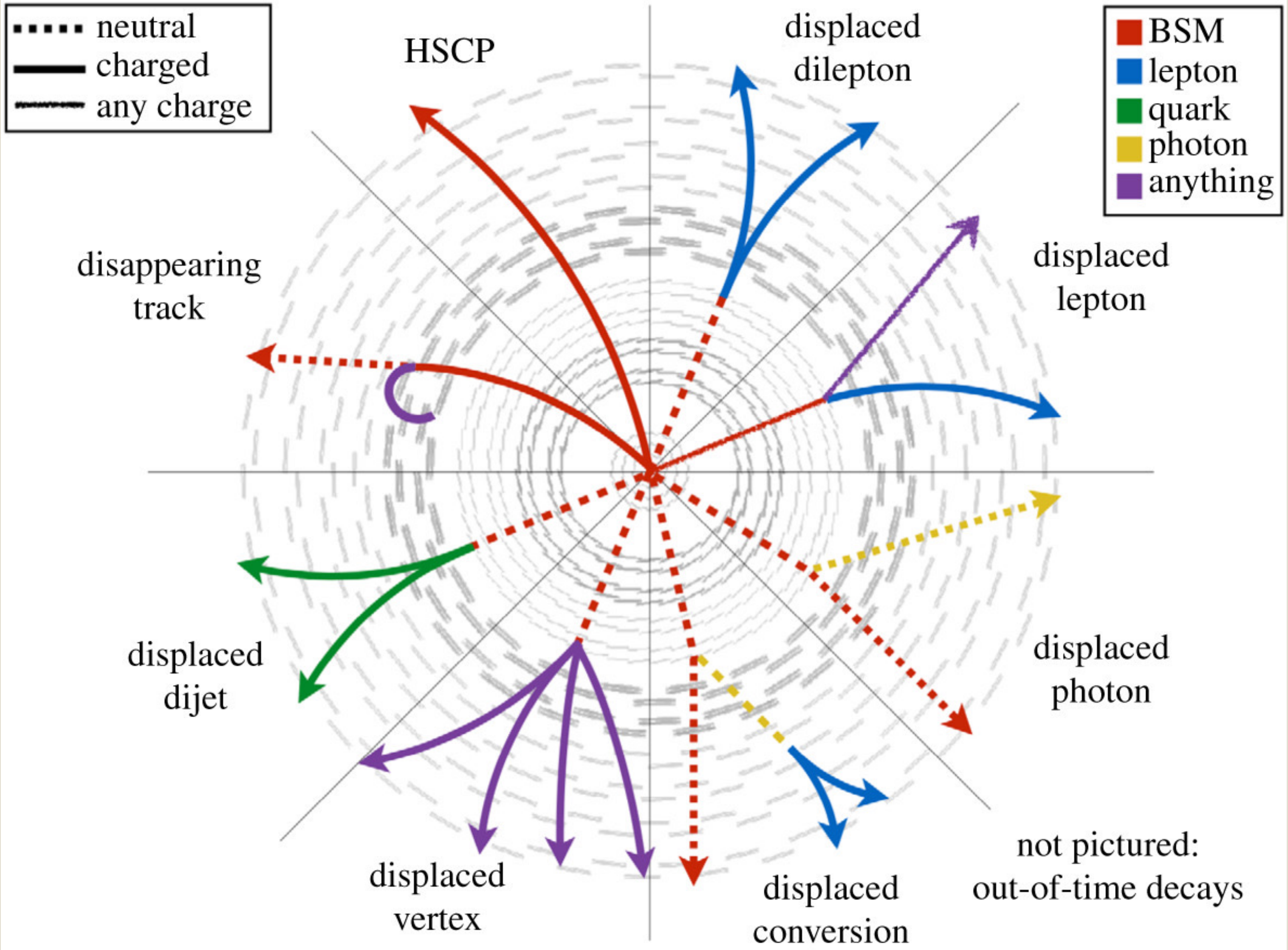


Figure from [A. De Roeck, Phil. Trans. Roy. Soc. Lond. A 377, 20190047 (2019)]

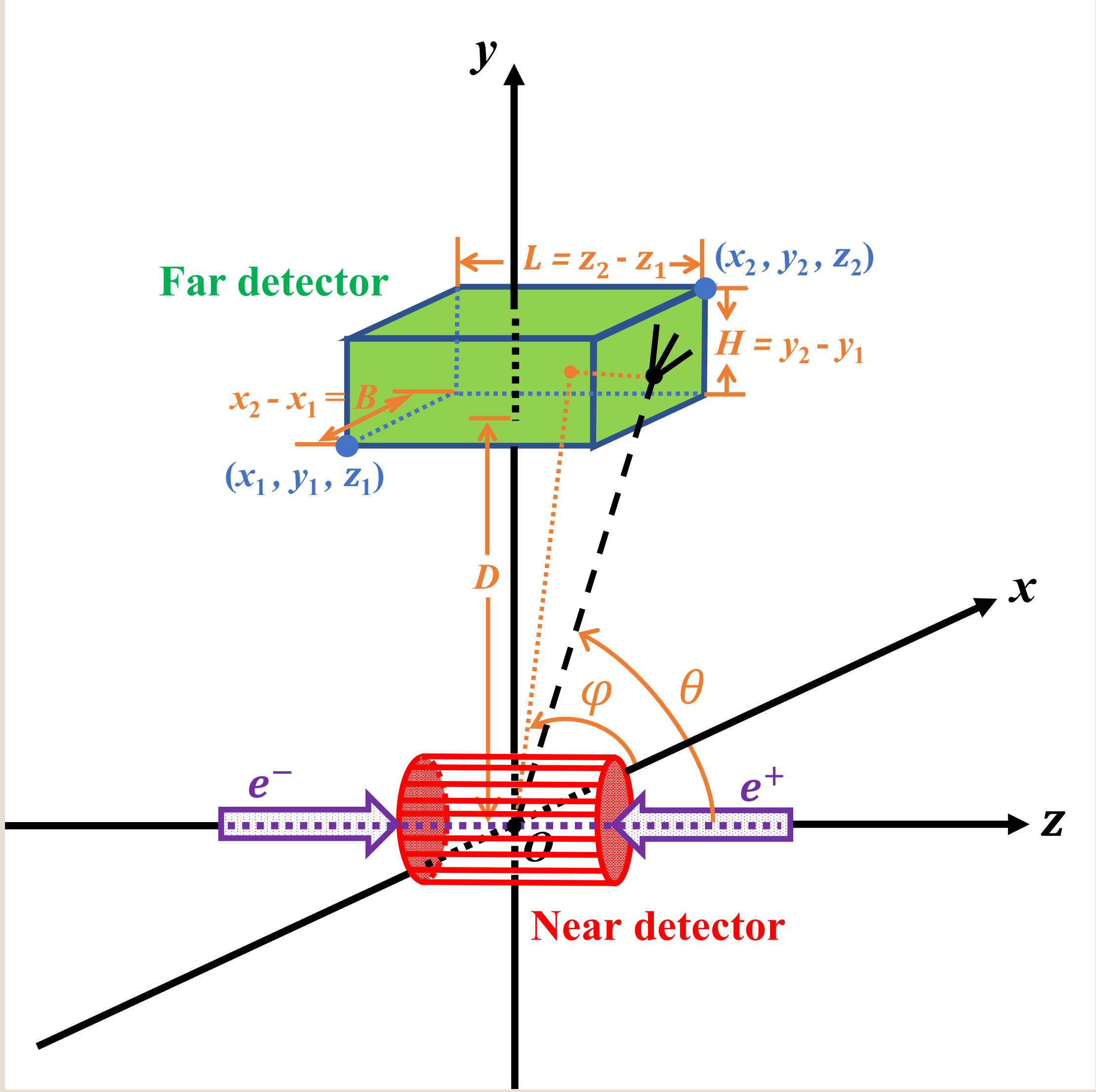
Signatures of LLPs in FD

When $\lambda \sim \mathcal{O}(100)$ m,

Mainly travel through and acts as missing energy in the near detector.

Far detector is more likely to observe the decay process, and reconstruct the time, position, direction, momentum, mass, etc.

Far detector can enhance the discovery potential for LLPs with very long decay length.

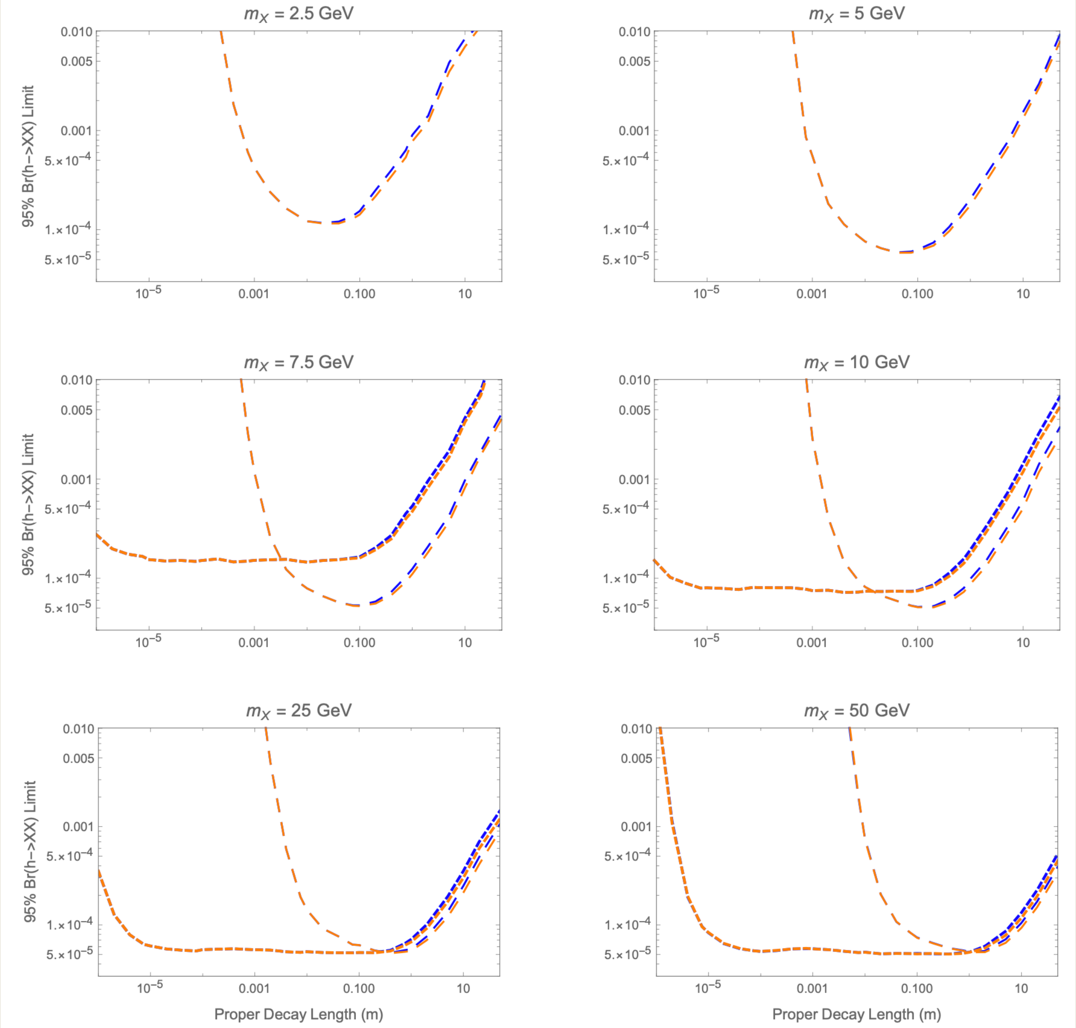


[**1911.06576, Zeren Simon Wang and Kechen Wang**, Physics with far detectors at future lepton colliders]

Higgs Decay

New scalars: $e^- e^+ \to HZ \to (XX)\,(l^- l^+)$ @ $\sqrt{s} = 250$ GeV

[**1812.05588, Samuel Alipour-Fard, Nathaniel Craig, Minyuan Jiang, and Seth Koren**, Long Live the Higgs Factory: Higgs Decays to Long-Lived Particles at Future Lepton Colliders]



In the zero-background regime, Poisson statistics rules out model points which predict 3 or more signal events to 95% confidence (or better) if no signal is detected. We may then find a projected 95% upper limit on branching ratio as

$$\mathrm{Br}(h \to XX)^{95} = \frac{N_{sig}}{\mathcal{L} \times \sigma(e^+e^- \to hZ) \times \mathrm{Br}(Z \to \ell\ell) \times A \times \varepsilon}, \tag{3.1}$$

with $N_{sig} = 3$ and $A \times \varepsilon$ the result of our simulations. For both the CEPC and FCC-ee, the most recent integrated luminosity projections [4, 39] give $\mathcal{L} \times \sigma(e^+e^- \to hZ) = 1.1 \times 10^6$ Higgses produced.

Figure 1: Projected 95% $h \to XX$ branching ratio limits as a function of proper decay length for a variety of X masses. Blue lines are for CEPC and orange lines are for FCC-ee, and where only one is visible they overlap. The larger dashes are the 'long lifetime' analysis and the smaller dashes are the 'large mass' analysis.

Higgs Decay

New scalars: $h \to h_s h_s, h_s \to \mu^- \mu^+, \pi^- \pi^+$ @ $\sqrt{s} = 240$ GeV **Mirror glueballs:** $h \to 0^{++}0^{++}$, $0^{++} \to \xi\xi$ @ $\sqrt{s} = 240$ GeV

[**1911.08721, Kingman Cheung and Zeren Simon Wang**, Probing Long-lived Particles at Higgs Factories]

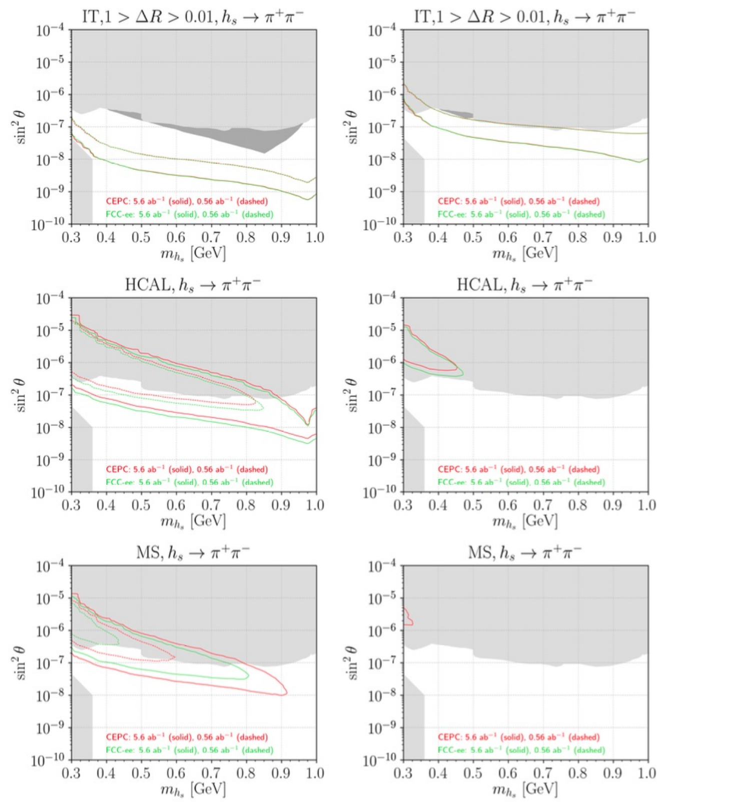


FIG. 5. Sensitivity reaches at the CEPC and FCC-ee for $h_s \to \pi^+\pi^-$. The left panels correspond to $\langle\chi\rangle = 10$ GeV while the right ones to $\langle\chi\rangle = 100$ GeV. The light gray area is experimentally excluded while the dark gray part shown in the upper row can be probed at the LHC with 300 fb^{-1} integrated luminosity.

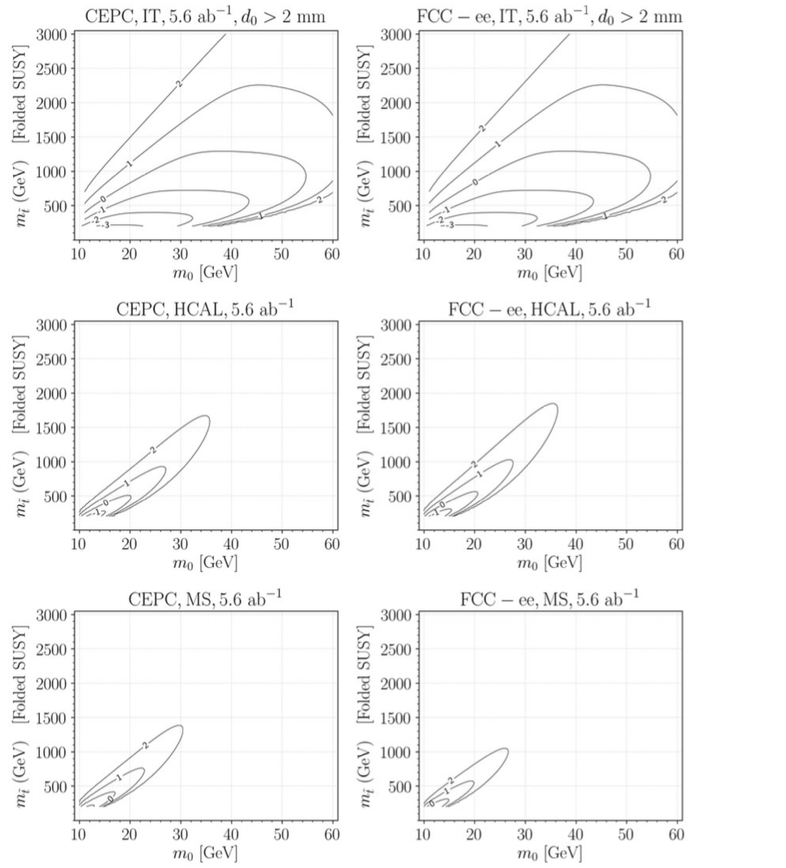
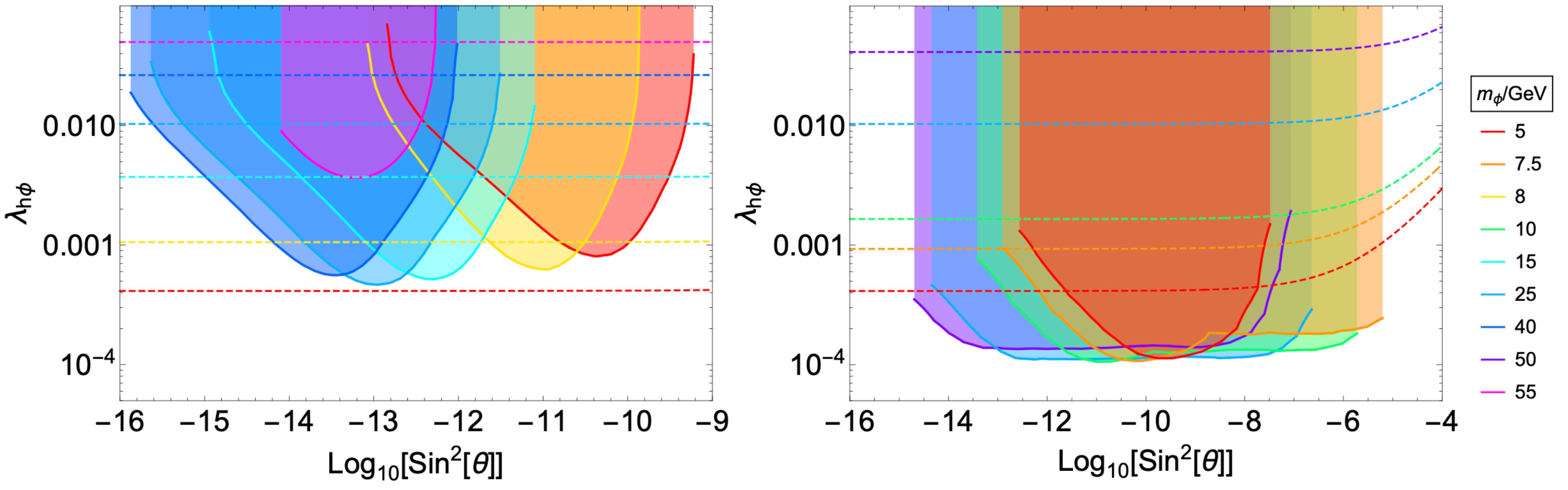


FIG. 7. Sensitivity reaches of $\log_{10}(\kappa)$ at the CEPC and FCC-ee for the Folded SUSY model for $N_{\rm signal} = 10$.

Higgs Decays

New scalars: $h \to \phi\phi$ @ $\sqrt{s} = 240$ GeV

[**2008.12773, Elina Fuchs, Oleksii Matsedonskyi, Inbar Savoray, Matthias Schlaffer**, Collider searches for scalar singlets across lifetimes]



(a) ATLAS $\sqrt{s} = 13$ TeV with 36 fb^{-1}.

(b) FCC-ee $\sqrt{s} = 240$ GeV with 5 ab^{-1}.

Figure 4. Bounds on $\lambda_{h\phi}$ and $\sin^2\theta$ for various singlet masses arising from searches for displaced jets in Higgs decays. The dashed lines show the upper naturalness limit $\lambda_{h\phi}^{\max} = m_\phi^2/v^2 + 4\pi m_\phi s_\theta/v$.

Higgs Decay

Hidden valley particles: $H \to \pi_V^0 \pi_V^0 \to (b\bar{b})(b\bar{b})$ @ $\sqrt{s}$ = 350 GeV & 3 TeV

[**2212.04147, Marcin Kucharczyk and Mateusz Goncerz**, Search for exotic decays of the Higgs boson into long-lived particles with jet pairs in the final state at CLIC]

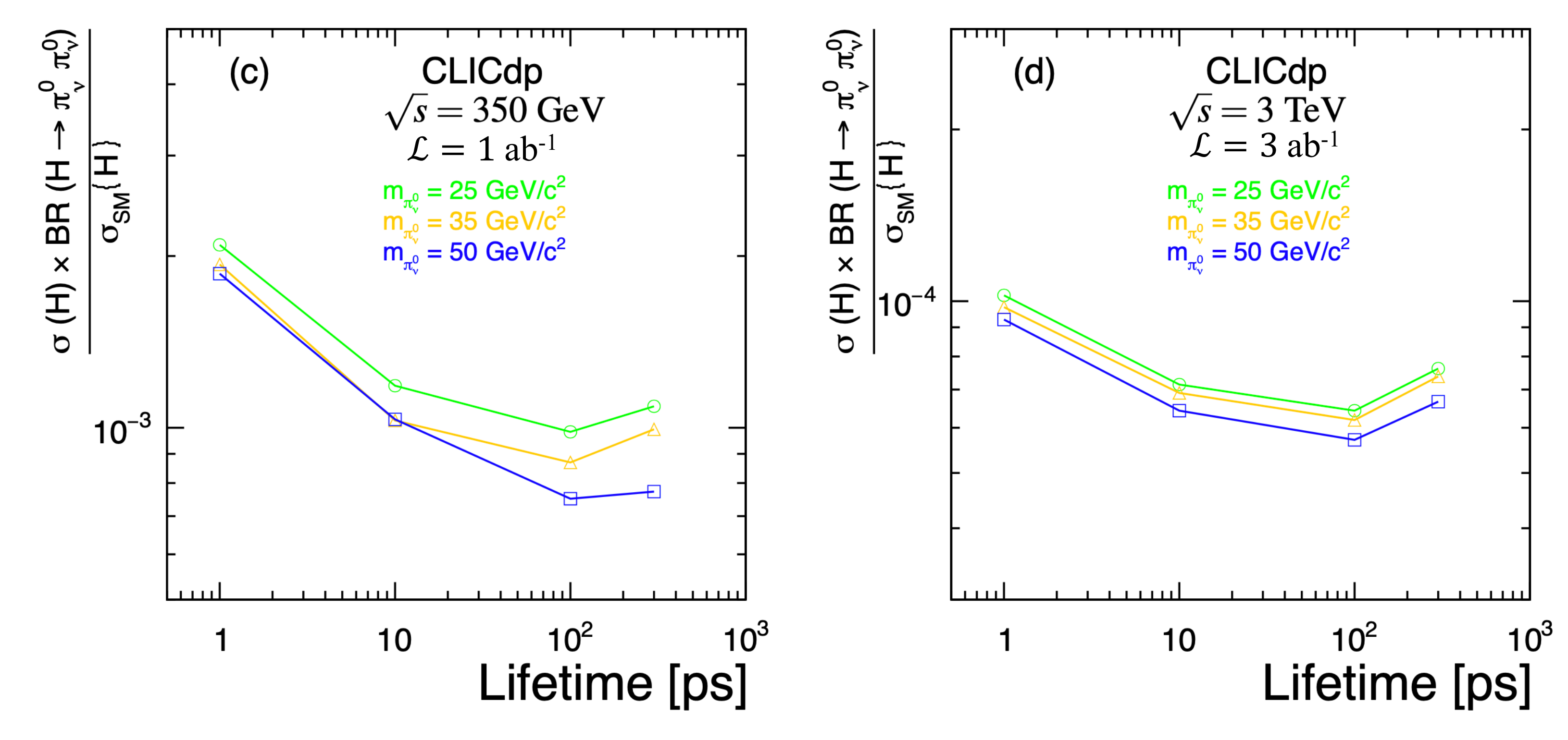


Figure 7: Expected 95% CL cross-section upper limits on the $\sigma(H) \times BR(H \to \pi_v^0 \pi_v^0)$, within the model [2], for three different π_v^0 masses: 25 GeV/c^2 (green), 35 GeV/c^2 (yellow), 50 GeV/c^2 (blue), as a function of π_v^0 lifetime for $\sqrt{s} = 350$ GeV (a) and $\sqrt{s} = 3$ TeV (b). The bottom row shows the upper limits normalized to the Standard Model production cross-section of the Higgs boson at $\sqrt{s} = 350$ GeV (c) and $\sqrt{s} = 3$ TeV (d).

Higgs Decays

Dark photon: $e^-e^+ \to HZ,\ H \to \gamma_D\gamma_D, \gamma_D \to f\bar{f}, l^-l^+$ @ $\sqrt{s} = 250$ GeV

[**2203.08347, Laura Jeanty, Laura Nosler, and Chris Potter**, Sensitivity to decays of long-lived dark photons at the ILC]

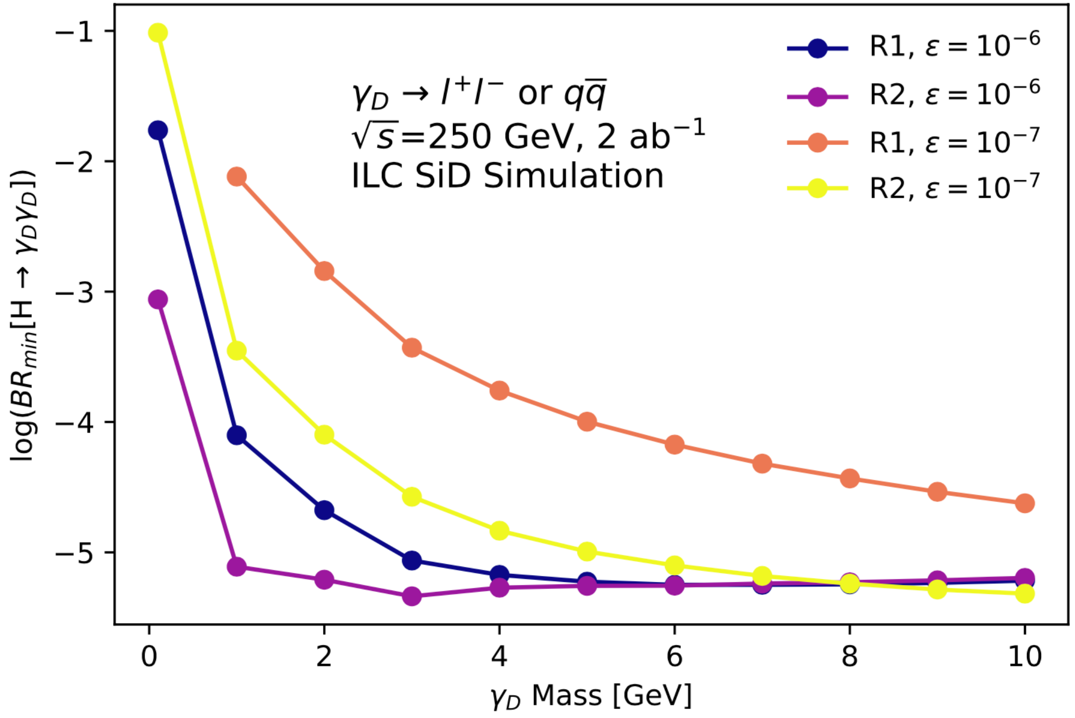


FIG. 6: The minimum branching ratio $H \to \gamma_D\gamma_D$ to which SiD will be sensitive for $\sqrt{s} = 250$ GeV and 2 ab^{-1}, when both leptonic and hadronic decays are reconstructed within the regions $R1$ and $R2$, for $\epsilon = 10^{-6}, 10^{-7}$.

Z Decays

RPV-SUSY neutralinos: $Z \to \tilde{\chi}_1^0 \tilde{\chi}_1^0,\ \tilde{\chi}_1^0 \to e^{\mp} K^{(*)\pm}, e^{\mp} jj$ @ $\sqrt{s} = 91.2$ GeV

[**1904.10661, Zeren Simon Wang, and Kechen Wang**, Long-lived light neutralinos at future Z−factories]

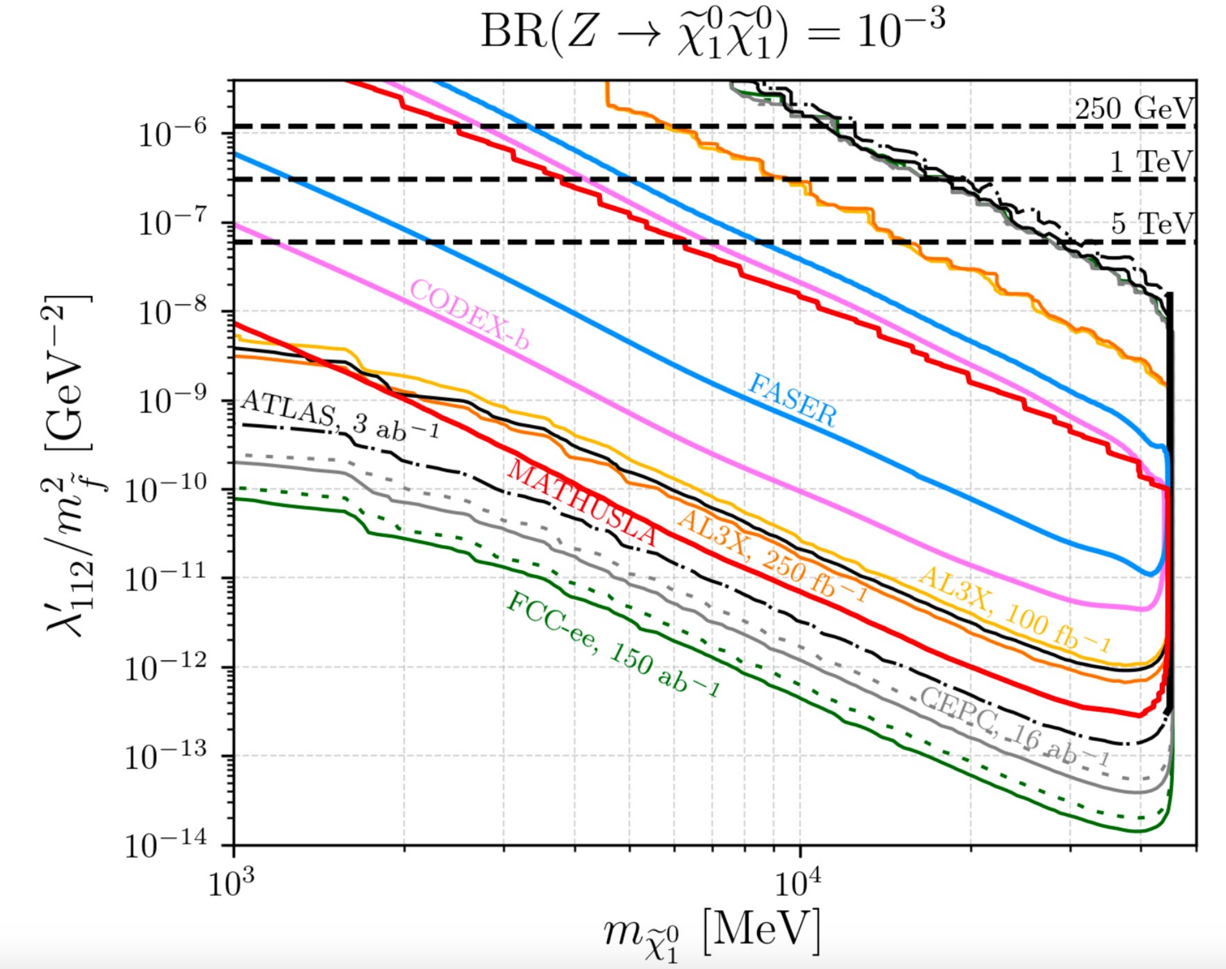
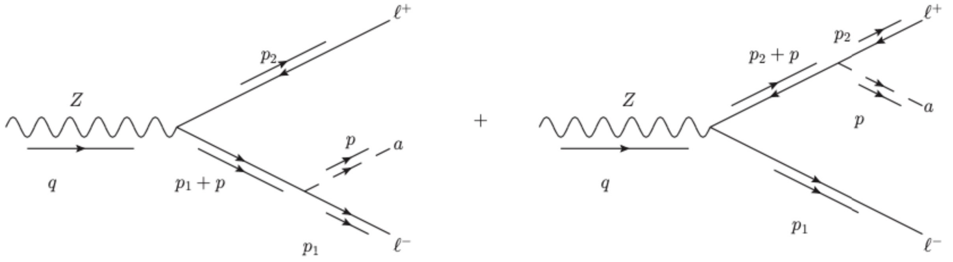


FIG. 1. The discovery limits of long-lived neutralinos for the near detector of CEPC/FCC-ee [7]. The solid contour curves correspond to three decay events in the fiducial volume when considering all decay modes of $\tilde{\chi}_1^0$, while the dashed lines include only visible/charged decay modes ($K^{(*)\pm} e^{\mp}$, $e^- us$ or $e^+ \bar{u}\bar{s}$). The estimates for experiments at the LHC: AL3X, CODEX-b, FASER and MATHUSLA, are reproduced from Refs. [8, 9]. The ATLAS results correspond to HL-LHC for $\sqrt{s} = 14$ TeV and 3 ab^{-1} integrated luminosity. The black horizontal dashed lines correspond to the current RPV bounds on the single coupling λ'_{112} [10] for three different degenerate sfermion masses $m_{\tilde{f}} = 250$ GeV, 1 TeV, and 5 TeV as labelled.

Z Decays

Axion like particles: $e^- e^+ \to Z^{(*)} \to l^- l^+ a$ @ $\sqrt{s} = 91$ GeV

[**2212.02818, Lorenzo Calibbi, Zijie Huang, Shaoyang Qin, Yiming Yang, and Xiaoyue Yin**, Testing axion couplings to leptons in Z decays at future e-e+ colliders]



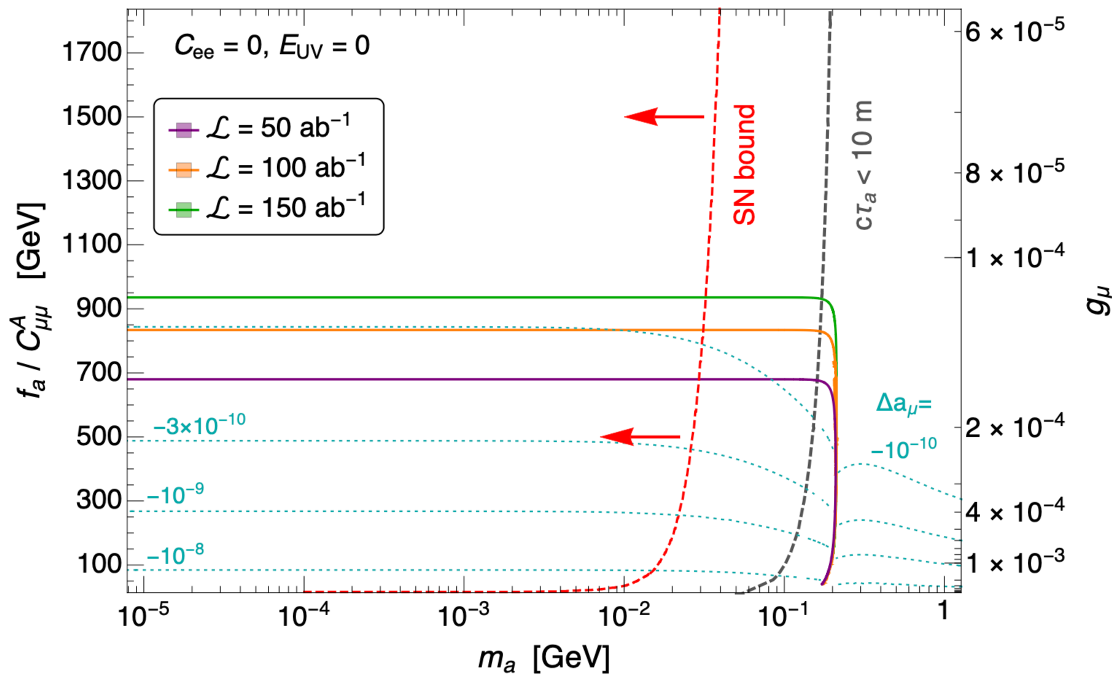
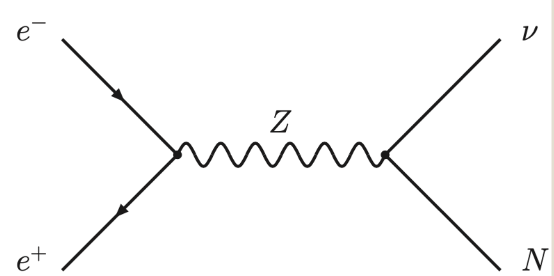


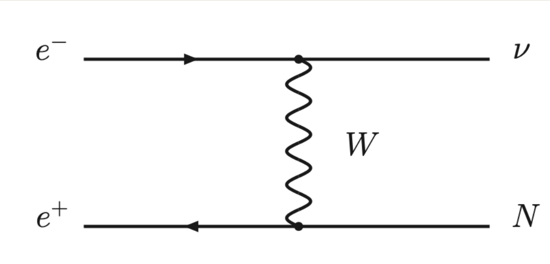
Figure 4: Prospected CEPC/FCC-ee 95% CL exclusion on the $(m_a,\ f_a/C^A_{\mu\mu})$ plane for a muonic ALP ($C^A_{ee} = 0$, $E_{\rm UV} = 0$) with different assumptions for the integrated luminosity $\mathcal{L}$, as indicated. On the right side of the dashed grey line the proper decay length of the ALP, as calculated using Eq. (8), is $c\tau_a < 10$ m. The region to the left of the red dashed line is excluded by SN1987A data, according to the analysis in [35]. The dotted cyan contours show the ALP contribution to the anomalous magnetic moment of the muon, $\Delta a_\mu \equiv (g-2)_\mu/2$. See the main text for details.

Heavy Neutral Leptons

HNL: $e^-e^+ \to \nu\, N$ @ $\sqrt{s} = 240, 350, 500$ GeV

[**1604.0242, Stefan Antusch, Eros Cazzato, Oliver Fischer**, Displaced vertex searches for sterile neutrinos at future lepton colliders]





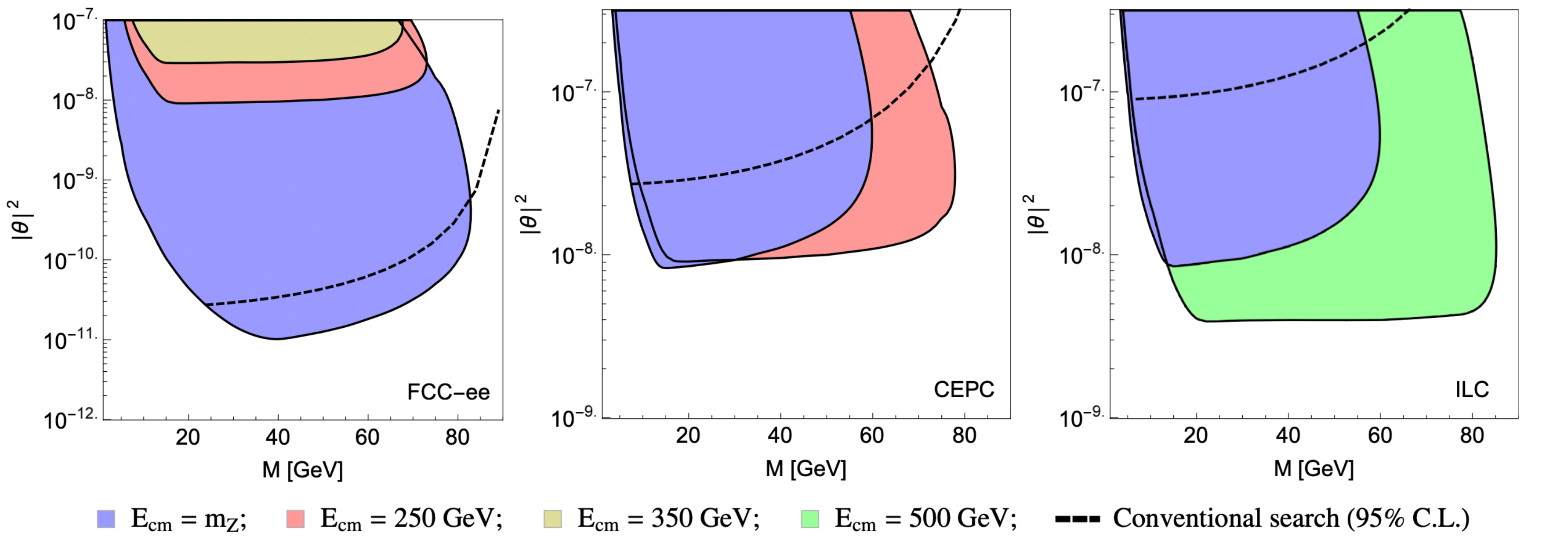


Figure 8: Sensitivity at 2σ for sterile neutrino searches via displaced vertices at the FCC-ee, the CEPC, and the ILC, assuming 100% signal efficiency. The colors denote the different modi operandi from fig. 4. The sensitivities for $E_{cm} \neq m_Z$ are understood for $|\theta|^2 = |\theta_e|^2$ (and $\theta_\mu, \theta_\tau = 0$). The SiD is used as benchmark detector for all the lepton collider experiments, for which we found heavy neutrino signals with vertex displacements between 10 μm and 249 cm to be essentially free of irreducible background, cf. section 4.2. The black dashed lines denote the conventional Z pole searches (cf. [10]).

Heavy Neutral Leptons

HNL: $e^- e^+ \to \nu\, N, NN; N \to \nu\gamma, 3f$ @ $\sqrt{s}$ = 91.2 GeV, 240 GeV, 3 TeV

[**2201.11754, Daniele Barducci and Enrico Bertuzzo**, The see-saw portal at future Higgs factories: the role of dimension six operators]

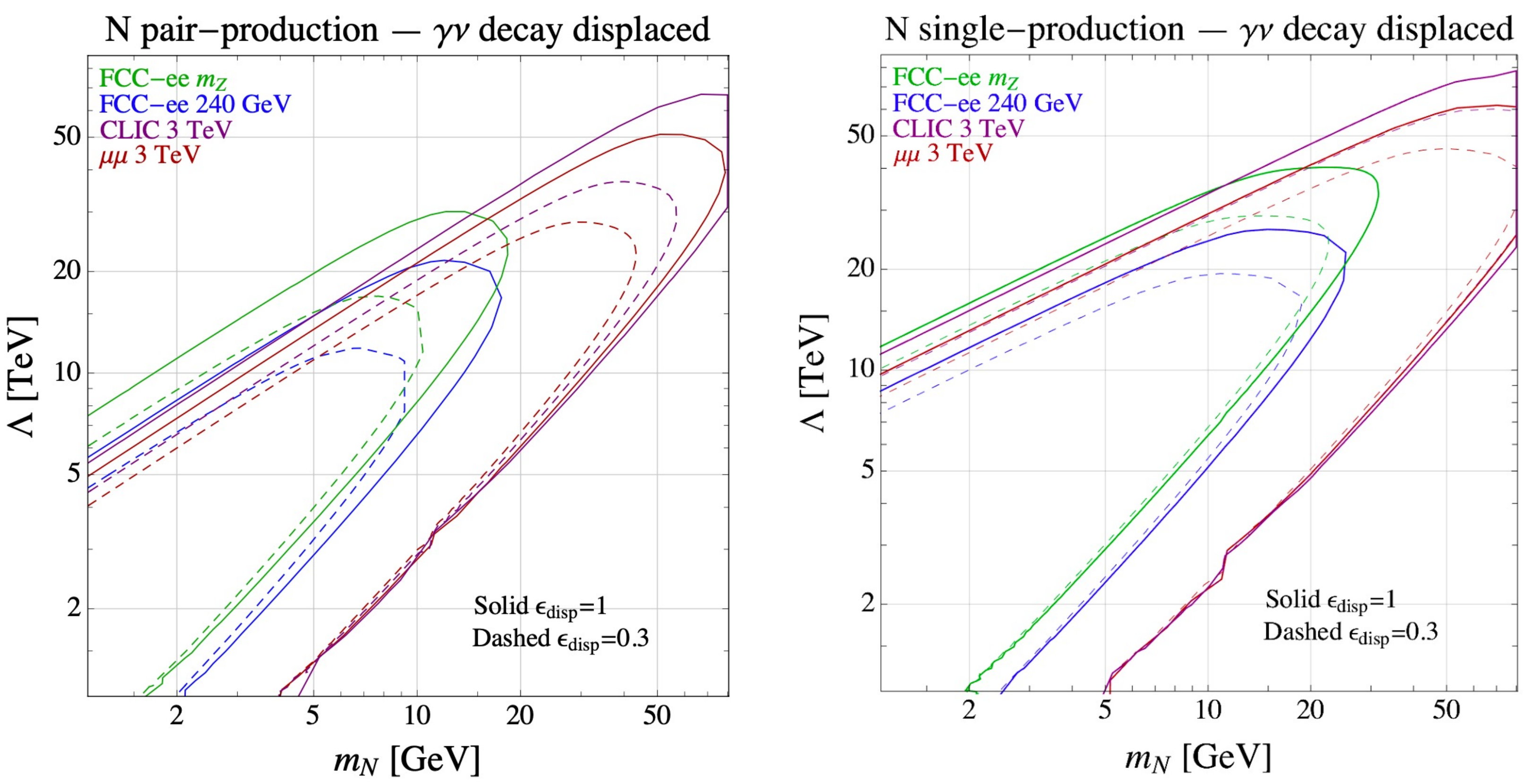
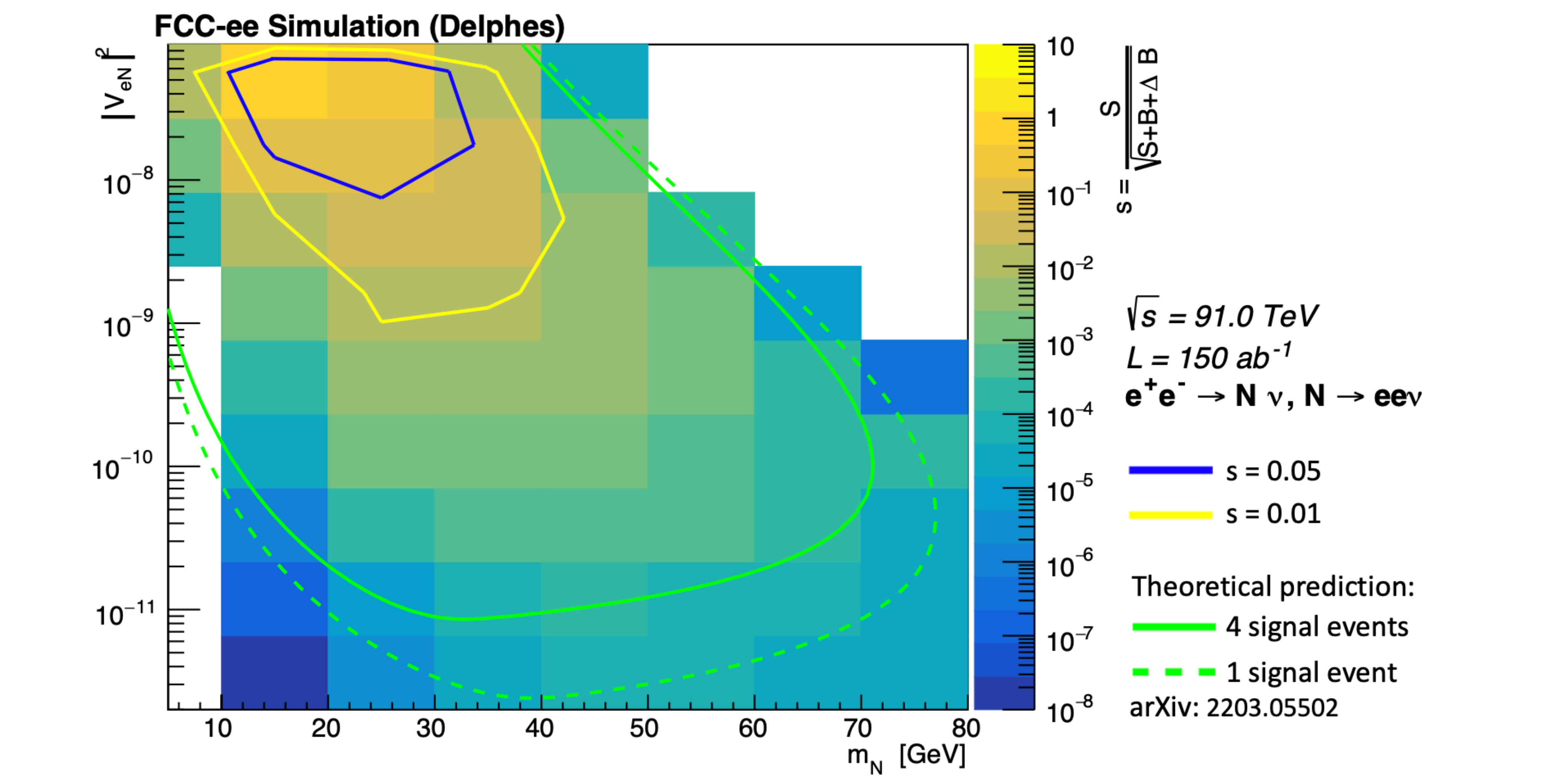


Figure 6. 95% CL exclusion limits for the displaced decay into a $\nu\gamma$ final state for pair produced (left) and singly produced (right) RH neutrinos. The solid lines correspond to $\epsilon_{\rm disp} = 1$ while the dashed ones to $\epsilon_{\rm disp} = 0.3$.

Heavy Neutral Leptons

HNL: $e^-e^+ \to \nu\, N,\ N \to ee\nu$ @ $\sqrt{s} = 91$ GeV

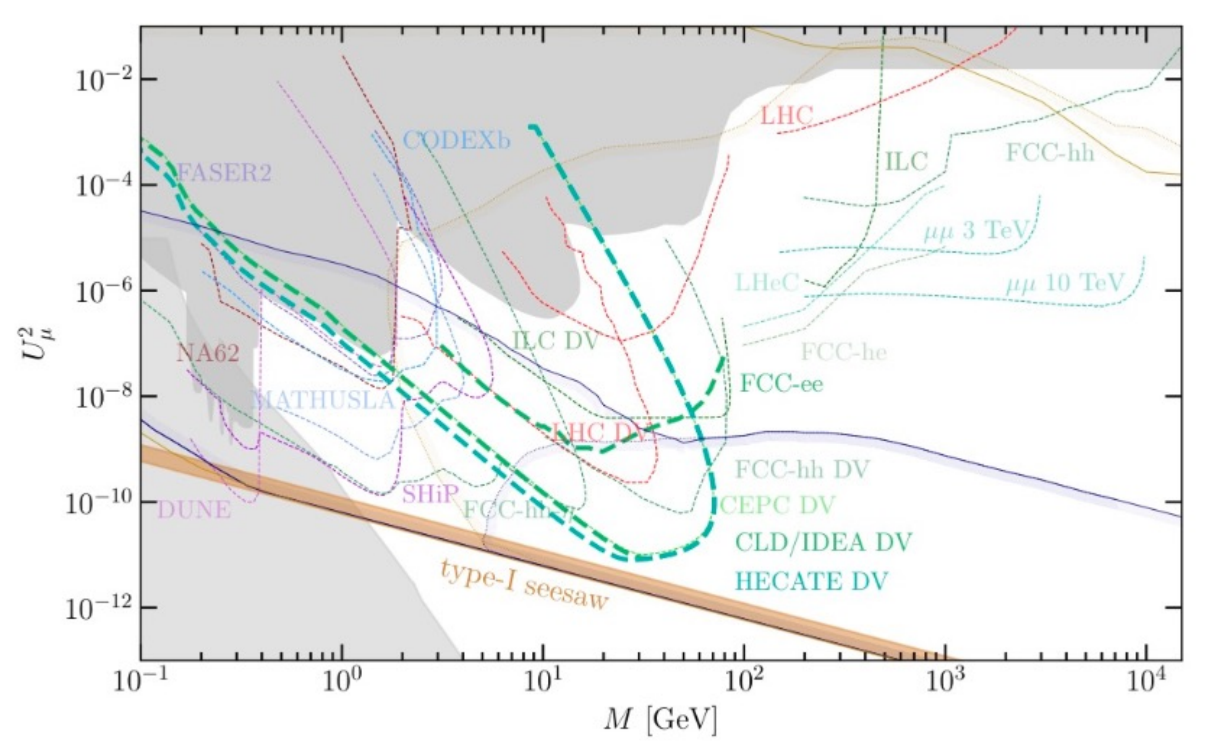
[**220601, Lovisa Rygaard**, Long-Lived Heavy Neutral Leptons at the FCC-ee]

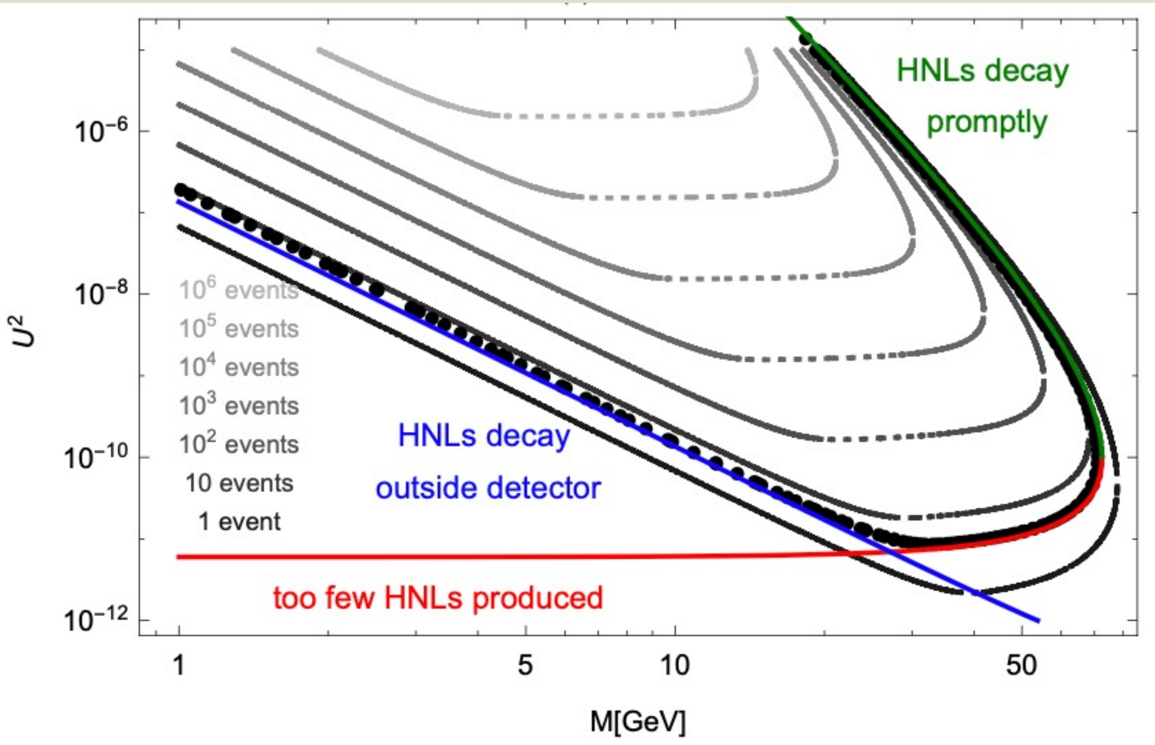


Heavy Neutral Leptons

HNL: $e^- e^+ \to \nu\, N$ @ $\sqrt{s} = 91.2$ GeV

[**2210.1711, Marco Drewes**, Distinguishing Dirac and Majorana Heavy Neutrinos at Lepton Colliders]





Heavy Neutral Leptons

HNL: $e^- e^+ \to Z,\ Z \to \nu\, N, N \to l^-\, l^+ \nu, \gamma\nu @ \sqrt{s} = 91.2$ GeV

[**2301.08592, Maksym Ovchynnikov and Jing-Yu Zhu**, Search for the dipole portal of heavy neutral leptons at future colliders]

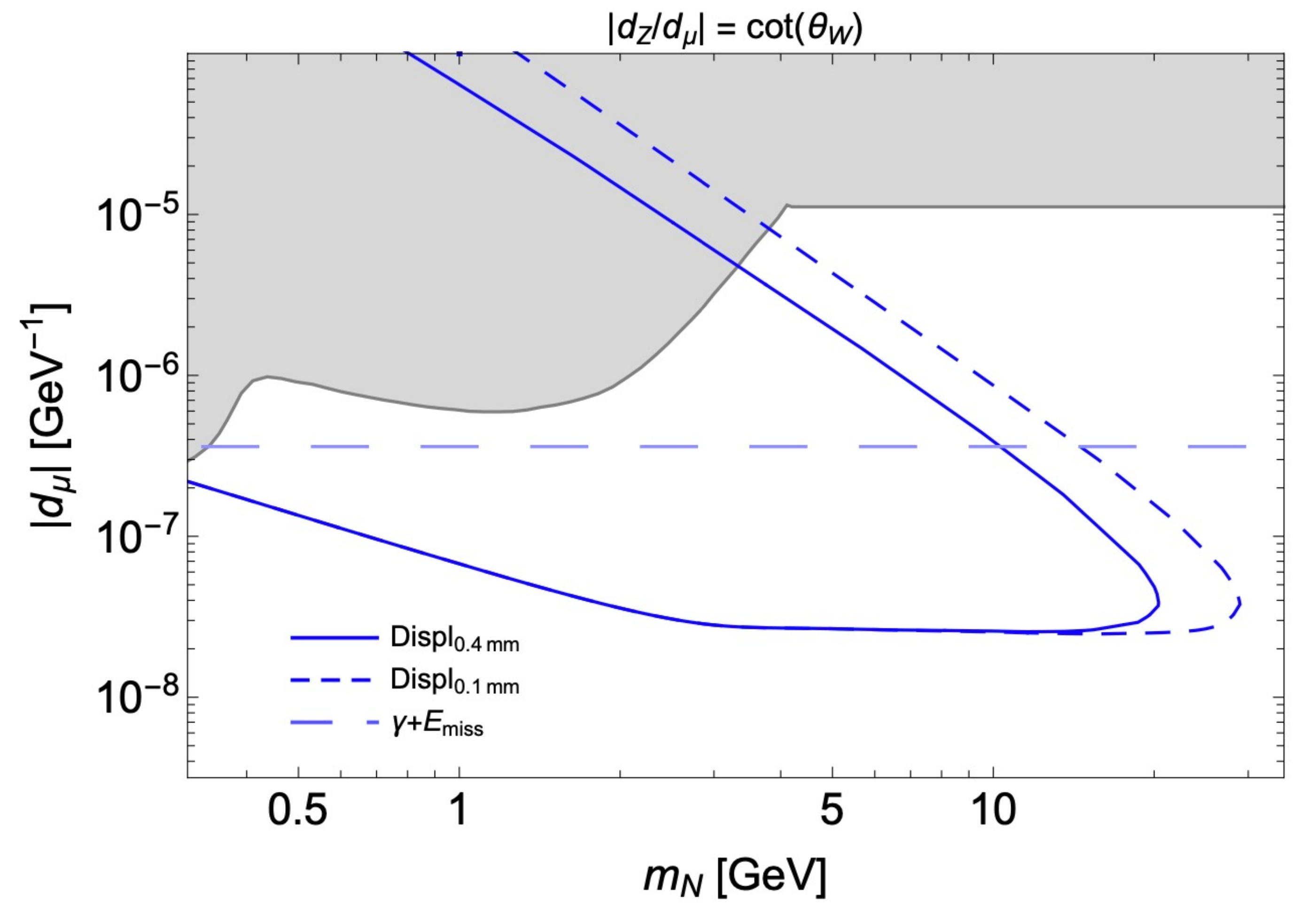


Figure 8: The potential of FCC-ee to probe the parameter space of the HNLs with the dipole coupling, see Sec. II B 2. The solid and short-dashed dark blue lines show the 90% CL sensitivity corresponding to the displaced decay signature, assuming the event selection considered in this paper (see Sec. IV A and Table III). The long-dashed lighter blue line denotes the sensitivity corresponding to the γ+missing energy signature.

SUSY

[**1211.21950, Jan Heisig**, Long-lived charged sleptons at the ILC/CLIC]

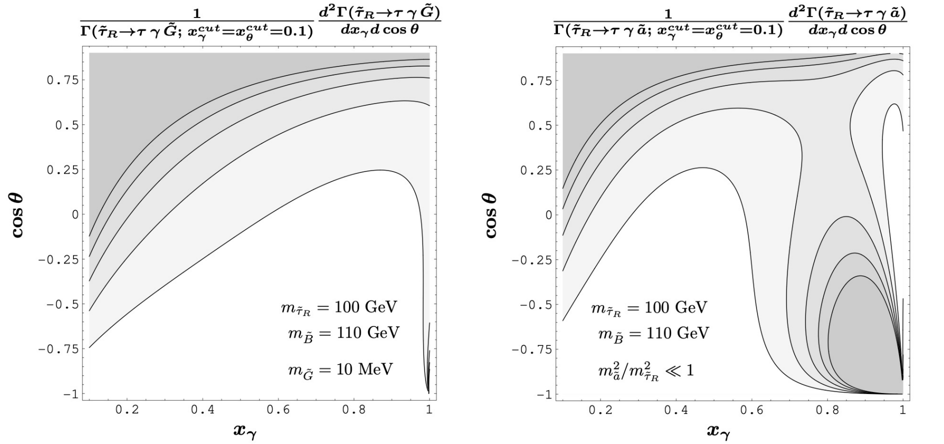


Figure 2: The normalized differential distributions of the visible decay products in the decays $\tilde{\tau} \to \tau\gamma\tilde{G}$ for the gravitino LSP scenario (left) and $\tilde{\tau} \to \tau\gamma\tilde{a}$ for the axino LSP scenario (right) for $m_{\tilde{\tau}_1} = 100$ GeV, $m_{\tilde{B}} = 110$ GeV, $m_{\tilde{a}}^2/m_{\tilde{\tau}_1}^2 \ll 1$, and $m_{\tilde{G}} = 10$ MeV. The contour lines represent the values 0.2, 0.4, 0.6, 0.8, and 1.0, where the darker shading implies a higher number of events. Taken from [13].

[**0709.1030, Hans-Ulrich Martyn**, Detection of long-lived staus and gravitinos at the ILC]

GMSB scenario SPS 7

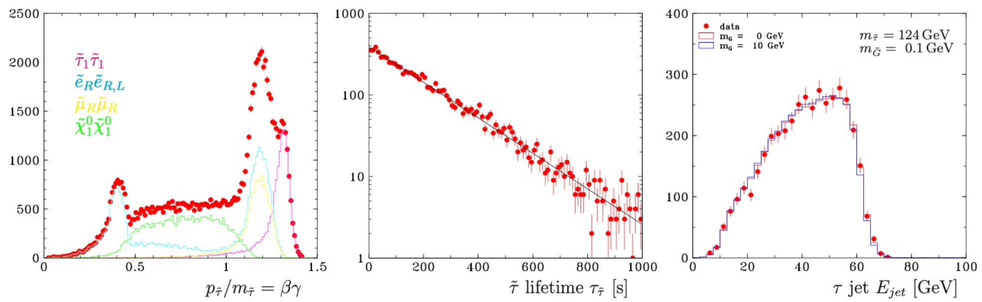


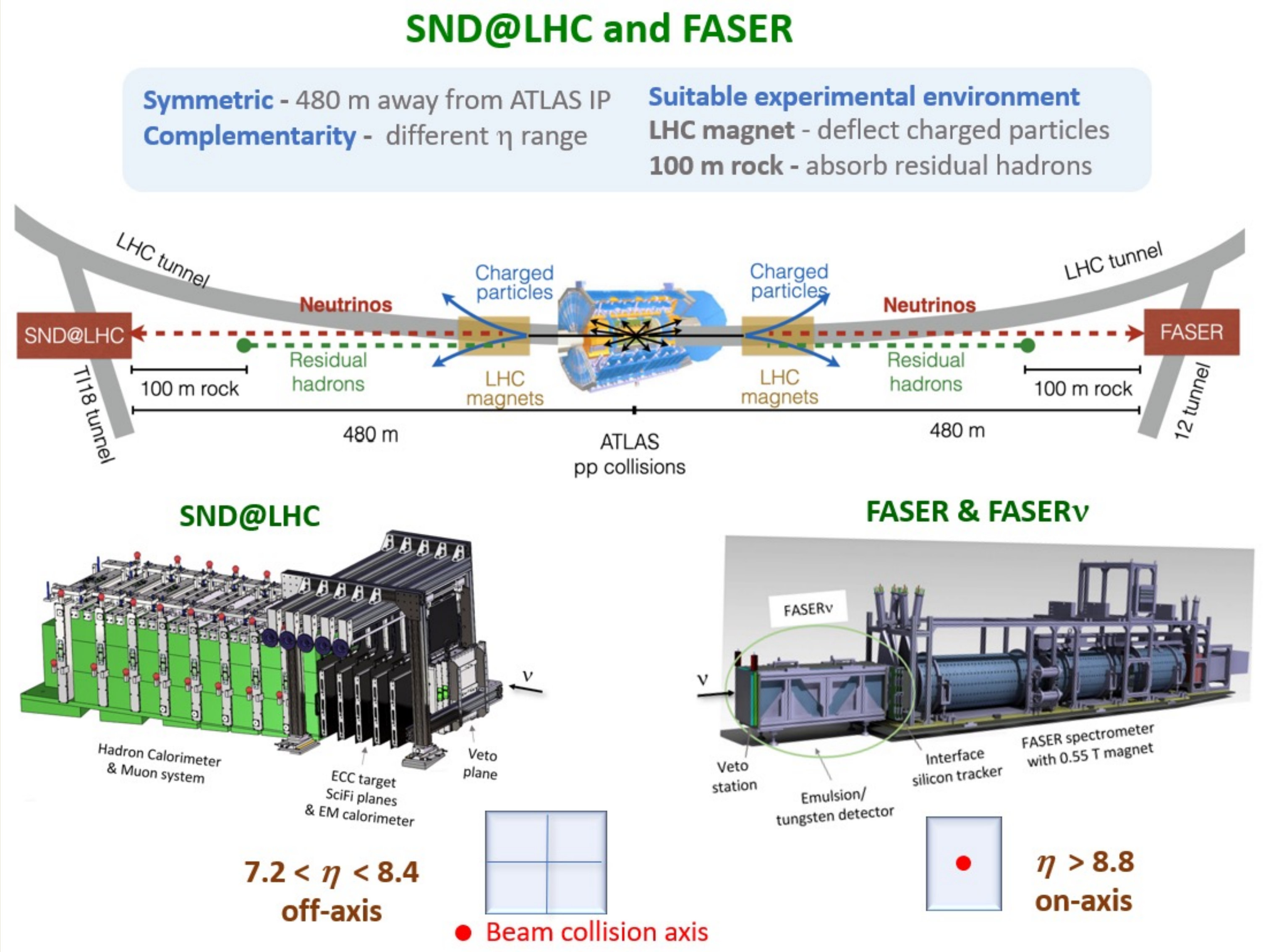
Fig. 3. SPS 7 scenario, assuming $\mathcal{L} = 100\,\mathrm{fb}^{-1}$ at $\sqrt{s} = 410$ GeV: (a) $\tilde{\tau}$ production spectra of scaled momentum $p/m = \beta\gamma$ with contributions from various processes; (b) $\tilde{\tau}$ lifetime distribution; (c) τ jet energy spectrum of the decay $\tilde{\tau}_1 \to \tau\tilde{G}$ compared with simulations of $m_{\tilde{G}} = 0$ GeV and 10 GeV

[**0606116, Alejandro Ibarra and Sourov Roy**, Lepton flavour violation in future linear colliders in the long-lived stau NLSP scenario]

We analyze the prospects of observing lepton flavour violation in future e^-e^- and e^+e^- linear colliders in scenarios where the gravitino is the lightest supersymmetric particle, and the stau is the next-to-lightest supersymmetric particle. The signals consist of multilepton final states with two heavily ionizing charged tracks produced by the long-lived staus. The Standard Model backgrounds

Far Detector

Current running FD experiments @ LHC



[http://www.ship-korea.com/SND.html]

[https://faser.web.cern.ch/index.php/]

[https://snd-lhc.web.cern.ch/]

[2210.02784, SND@LHC: The Scattering and Neutrino Detector at the LHC]

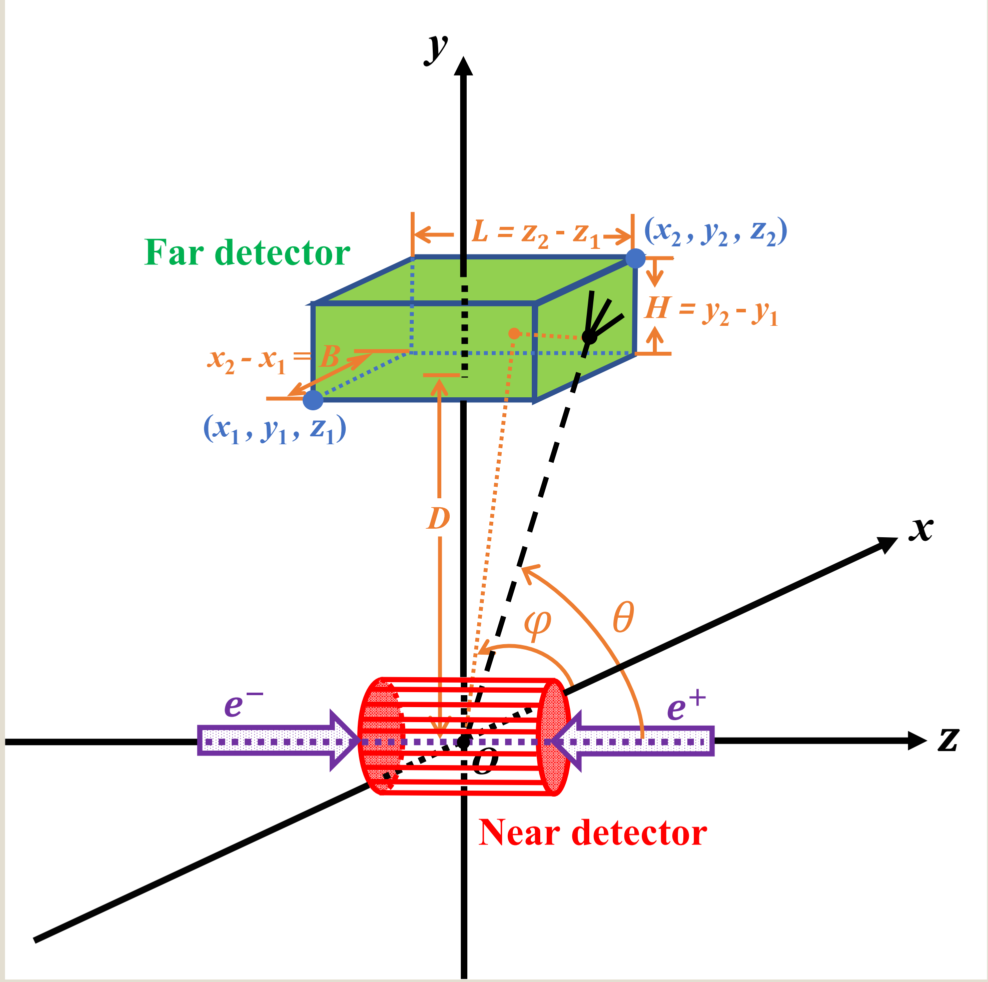
[2203.05090, The Forward Physics Facility at the High-Luminosity LHC]

Proposed FD experiments：
MATHUSLA; FASER2, FASERν2, AdvSND, FLArE, FORMOSA；CODEX-b；AL3X; ...

Far Detector

[**1911.06576, Zeren Simon Wang and Kechen Wang**, Physics with far detectors at future lepton colliders]

	V [m^3]	B [m]	H [m]	L [m]	(x_1, y_1, z_1) [m]	(x_2, y_2, z_2) [m]	D [m]
FD1	5.0×10^3	10	10	50	(5, -5, -25)	(15, 5, 25)	5
					(10, -5, -25)	(20, 5, 25)	10
FD2	8.0×10^5	200	20	200	(-100, 50, 50)	(100, 70, 250)	50
					(-100, 100, 100)	(100, 120, 300)	100
FD3	8.0×10^5	200	20	200	(-100, 50, -100)	(100, 70, 100)	50
					(-100, 100, -100)	(100, 120, 100)	100
FD4	8.0×10^5	100	80	100	(-50, 50, -50)	(50, 130, 50)	50
					(-50, 100, -50)	(50, 180, 50)	100
FD5	3.2×10^6	200	80	200	(-100, 50, -100)	(100, 130, 100)	50
					(-100, 100, -100)	(100, 180, 100)	100
FD6	8.0×10^7	1000	80	1000	(-500, 50, -500)	(500, 130, 500)	50
					(-500, 100, -500)	(500, 180, 500)	100
FD7	8.0×10^5	2000	20	20	(-1000, 50, -10)	(1000, 70, 10)	50
					(-1000, 100, -10)	(1000, 120, 10)	100
FD8	8.0×10^5	20	20	2000	(-10, 50, -1000)	(10, 70, 1000)	50
					(-10, 100, -1000)	(10, 120, 1000)	100



Simple shape: cuboid, similar to MUTHUSLA
Varying: position & geometry size

Far Detector

[**1911.06576, Zeren Simon Wang and Kechen Wang**, Physics with far detectors at future lepton colliders]

Exotic Higgs Decays | Heavy Neutral Leptons | Light Neutralinos in RPV SUSY

scenario		$h \to XX$	$Z \to N\nu$	$Z \to \tilde{\chi}_1^0 \tilde{\chi}_1^0$
LLP		X light scalar	N	$\tilde{\chi}_1^0$ light fermion
production $e^- e^+ \to$		Zh (main) $\nu\bar{\nu}h, e^- e^+ h$ (VBF)	Z	
$\sqrt{s}$ [GeV]		240	91.2	
N_h	CEPC FCC-ee	1.14×10^6 [16] 5.6 ab^{-1}, 7 years, 2 IPs	-	
N_Z	CEPC	-	7.0×10^{11} [16]	**16 ab^{-1}**, 2 years, 2 IPs
	FCC-ee		5.0×10^{12} [20]	**150 ab^{-1}**, 4 years, 2 IPs

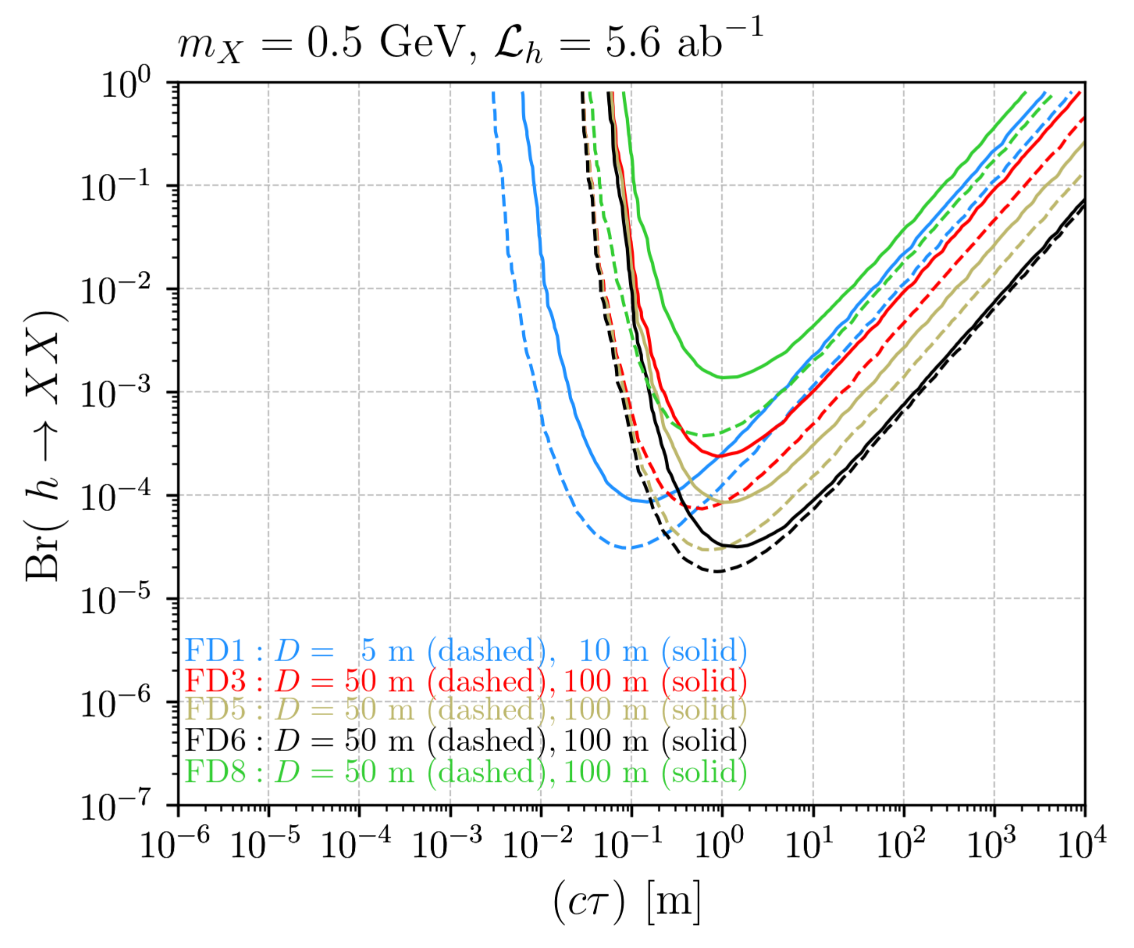
has been updated to 1.5×10^{12}

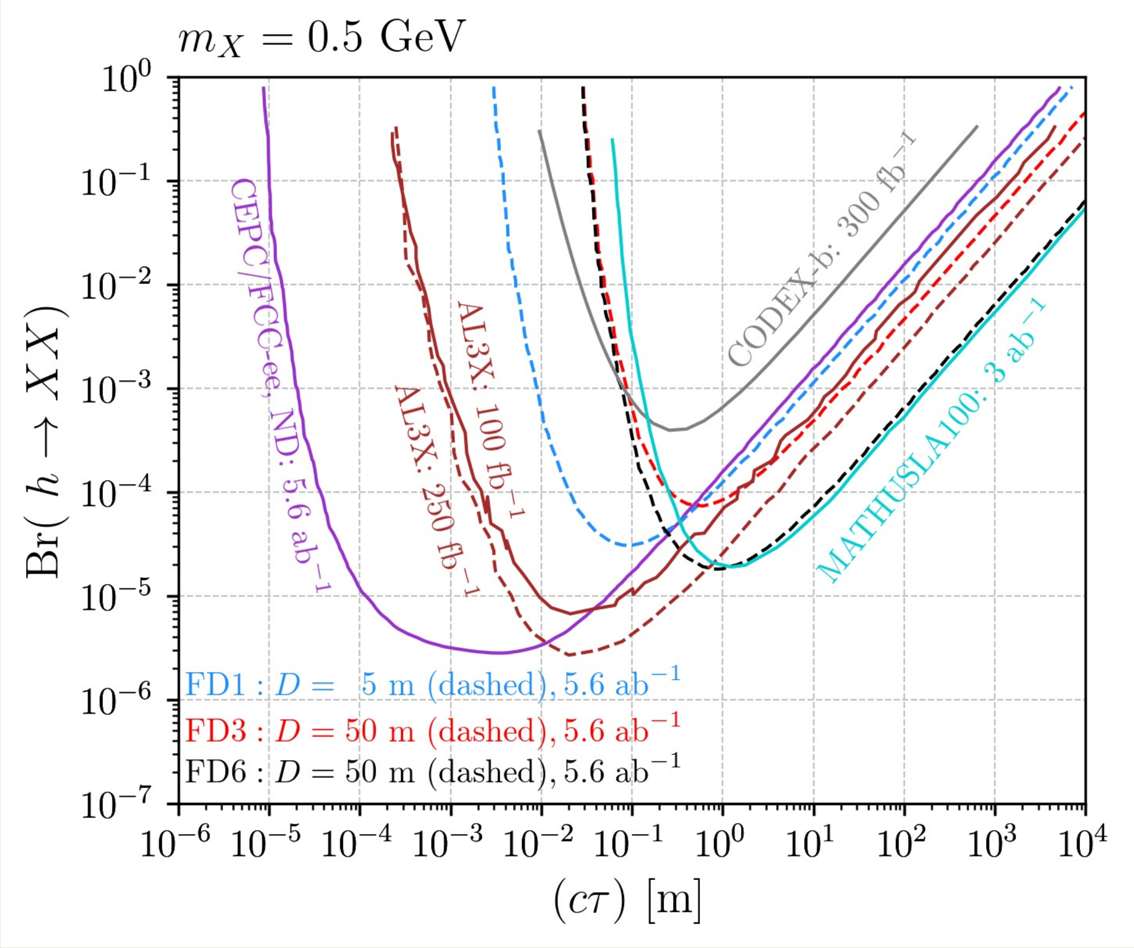
Results shown in [PRD 101 (2020) 075046]

Far Detector

Higgs decays: $h \to XX$ @ $\sqrt{s} = 240$ GeV

[**1911.06576, Zeren Simon Wang and Kechen Wang**, Physics with far detectors at future lepton colliders]

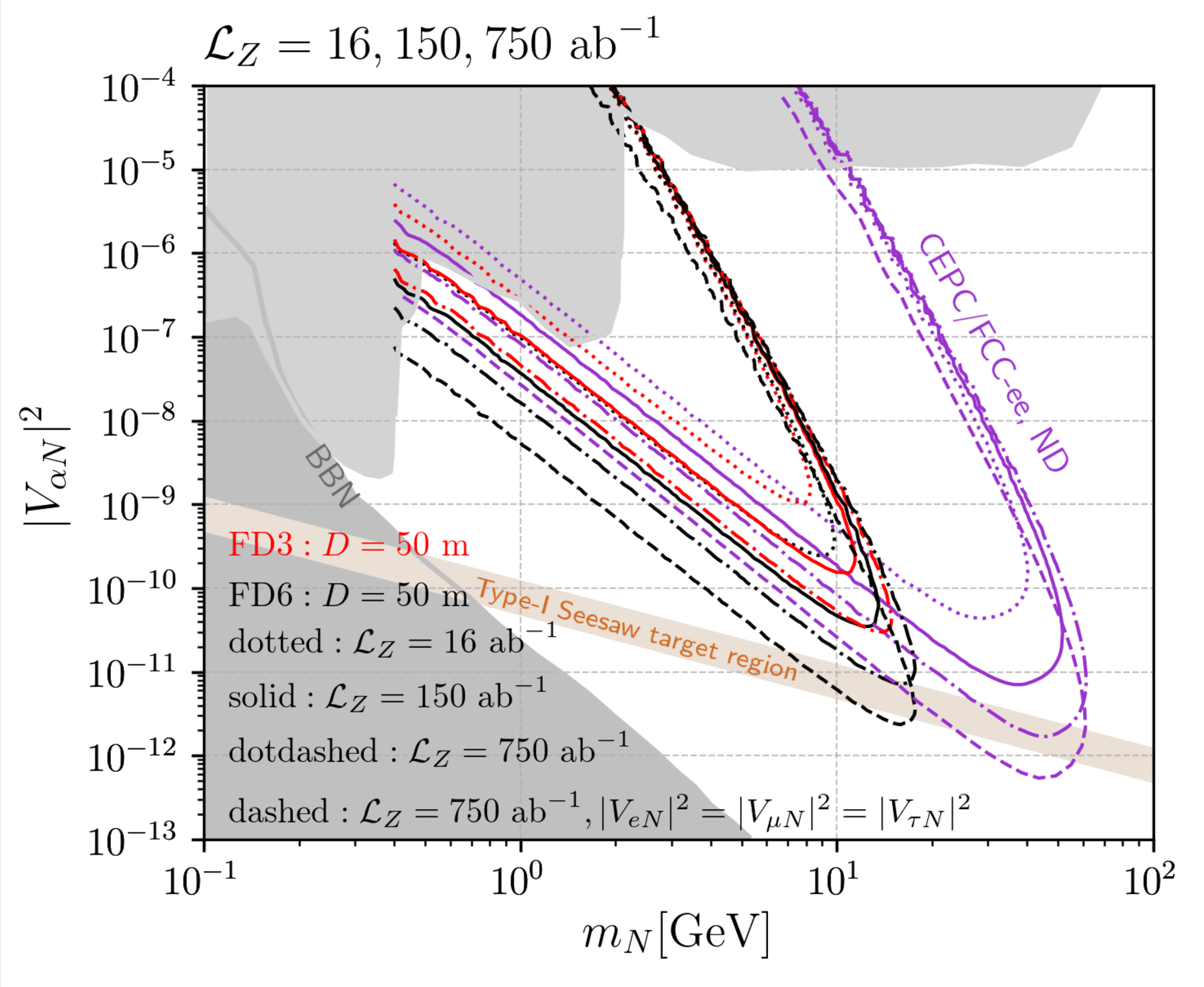




Far Detector

HNL: $Z \to N\nu$ @ $\sqrt{s} = 91.2$ GeV

[**1911.06576, Zeren Simon Wang and Kechen Wang**, Physics with far detectors at future lepton colliders]



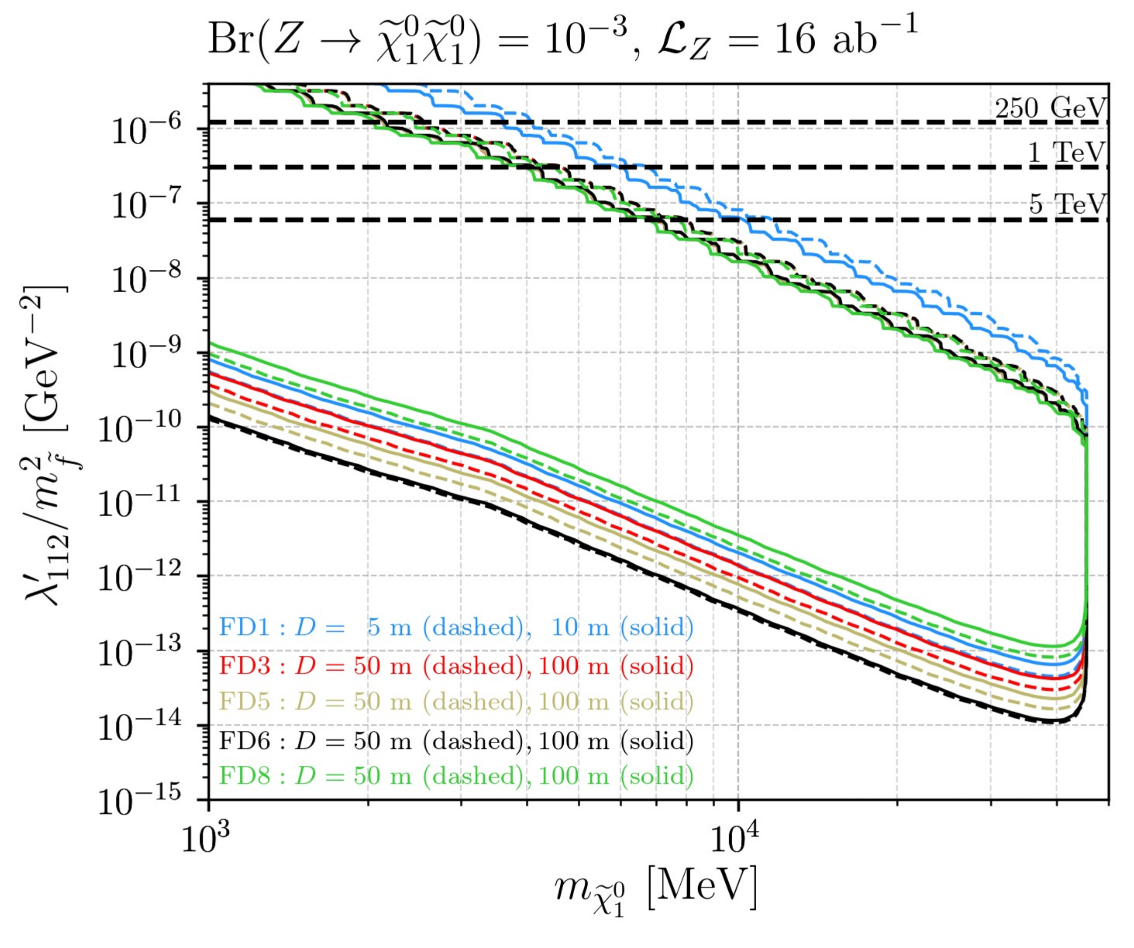
750 ab^{-1}, 10 years, 4 IPs;
or to increase the instantaneous luminosity;
or to relax the theoretical assumptions

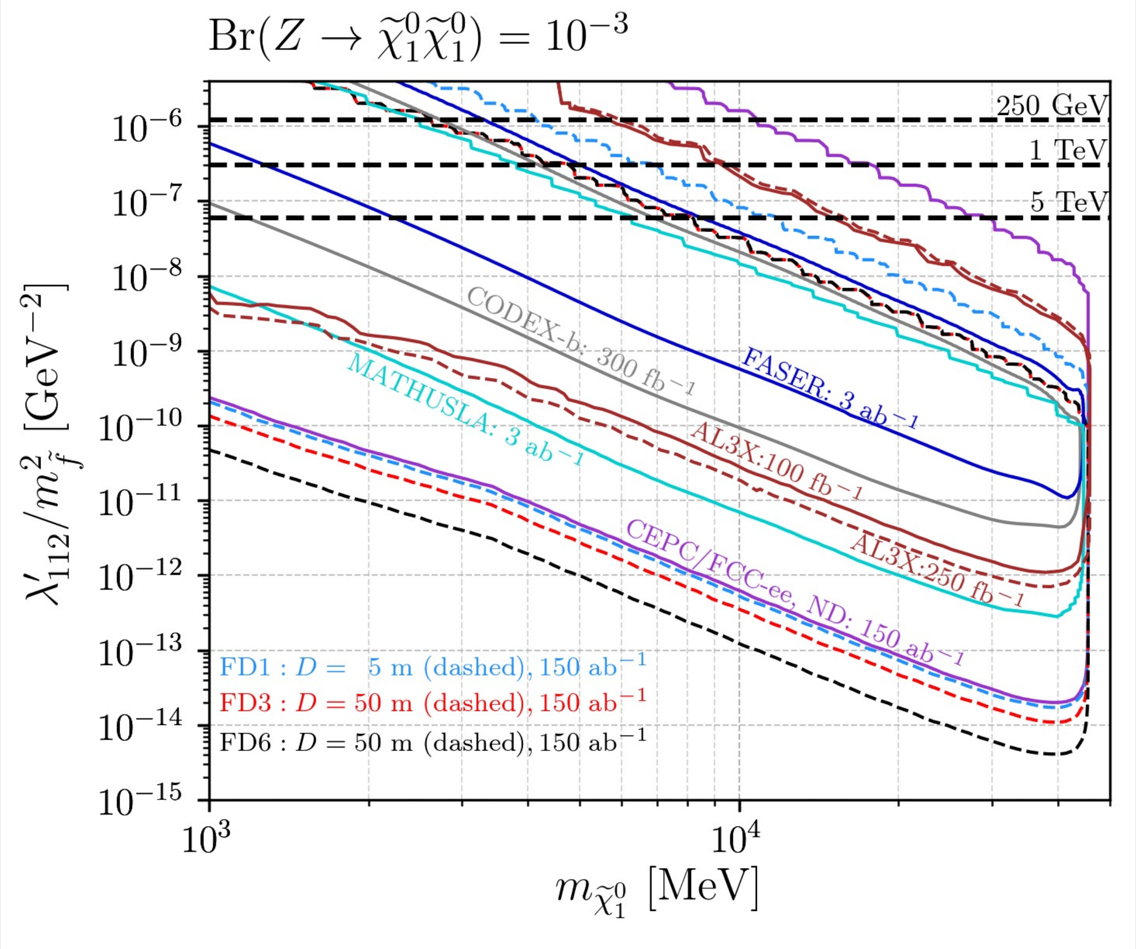
Can test the Type-I seesaw directly!

Far Detector

RPV-SUSY neutralinos: $Z \to \tilde{\chi}_1^0\,\tilde{\chi}_1^0$ @ $\sqrt{s} = 91.2$ GeV

[**1911.06576, Zeren Simon Wang and Kechen Wang**, Physics with far detectors at future lepton colliders]

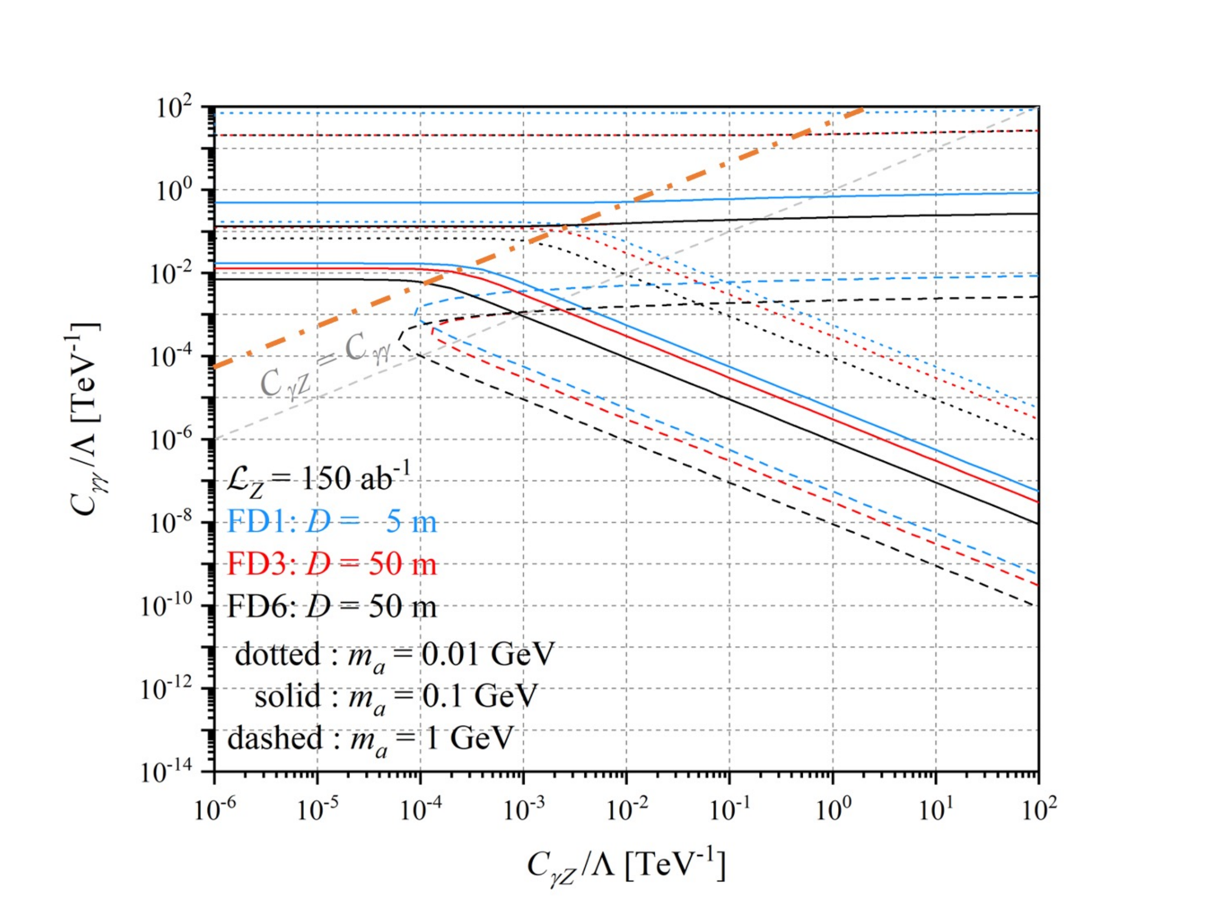


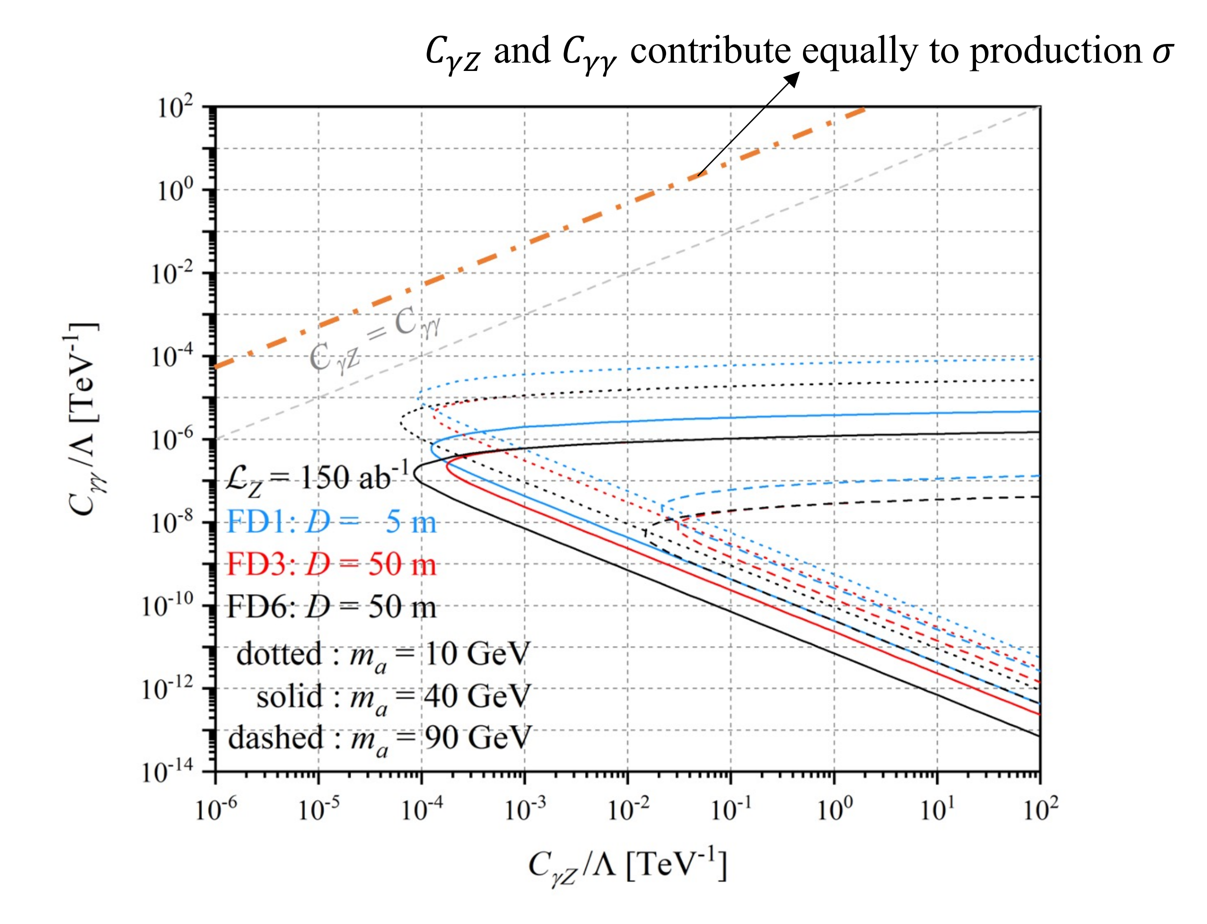


Far Detector

Axion like particles: $e^-e^+ \to \gamma\, a,\ a \to \gamma\gamma$ @ $\sqrt{s} = 91.2$ GeV

[**2201.0896, Minglun Tian, Zeren Simon Wang and Kechen Wang**, Search for long-lived axions with far detectors at future lepton colliders]





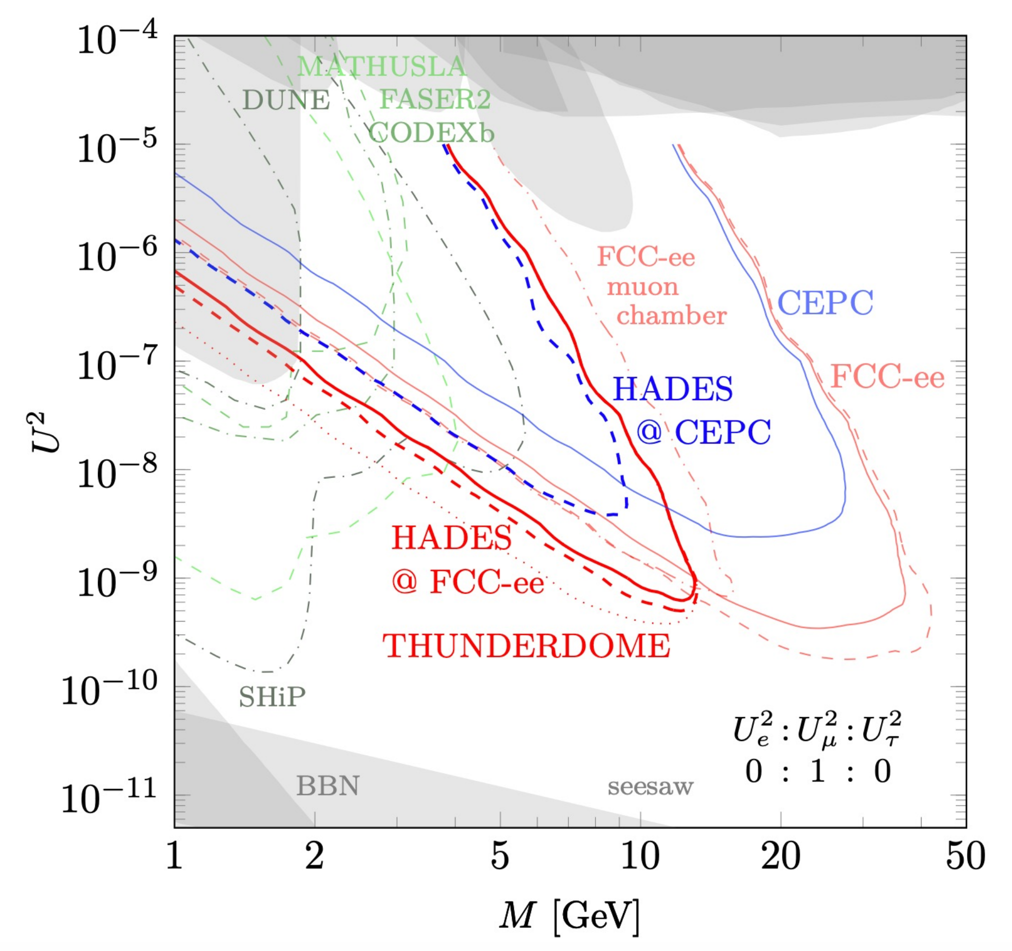
→ Discoverable regions shift downward with increasing m_a

→ Discovery regions shift rightward when $m_a > 40$ GeV

Far Detector

HNL: $Z \rightarrow N\nu$ @ $\sqrt{s} = 91.2$ GeV

[**2011.01005, Marcin Chrzaszcz, Marco Drewes, and Jan Hajer**, HECATE: A long-lived particle detector concept for the FCC-ee or CEPC]



The HADES detector would consist of scintillator plates located around the cavern walls forming a 4π detector.

Figure 1: Comparison of the sensitivities (9 events) that can be achieved at the FCC-ee with $2.5 \cdot 10^{12}$ Z-bosons (red) or CEPC with $3.5 \cdot 10^{11}$ Z-bosons (blue).

Far Detector

Axion like particles: $e^-e^+ \to \gamma a, a \to \gamma Z \to \gamma\ (\gamma a) @ \sqrt{s} = 250$ GeV

[**2202.11714, Ruth Schäfer, Finn Tillinger, Susanne Westhoff**, Near or far detectors? A case study for long-lived particle searches at electron-positron colliders]

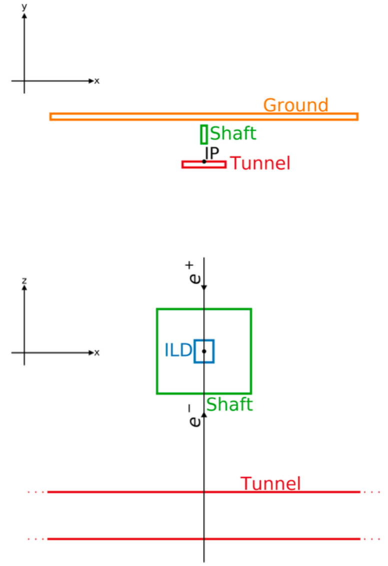


Figure 3: Far detector options around the ILC interaction point (IP). Shown are a side view (left) and top view (right) of the projected far detectors in the Shaft (S, blue), in the Tunnel (T, purple), and on the Ground (G, red), as well as the main detector ILD (green). The Ground detector is centered around $(x, z) = (0, 0)$ and is too large to appear in the top view.

- Shaft (S): $18 \times 30 \times 18$ m, centered around $(0, 45, 0)$ m
- Tunnel (T): $140 \times 10 \times 10$ m, centered around $(0, -5, -35)$ m
- Ground (G): $1000 \times 10 \times 1000$ m, centered around $(0, 75, 0)$ m .

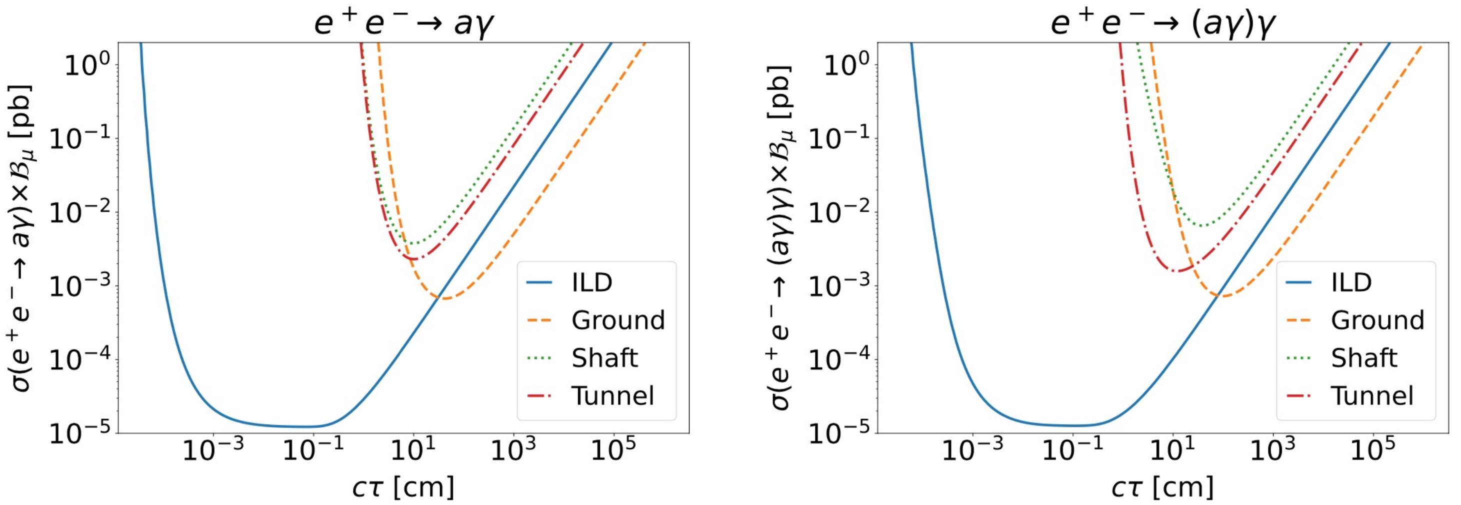
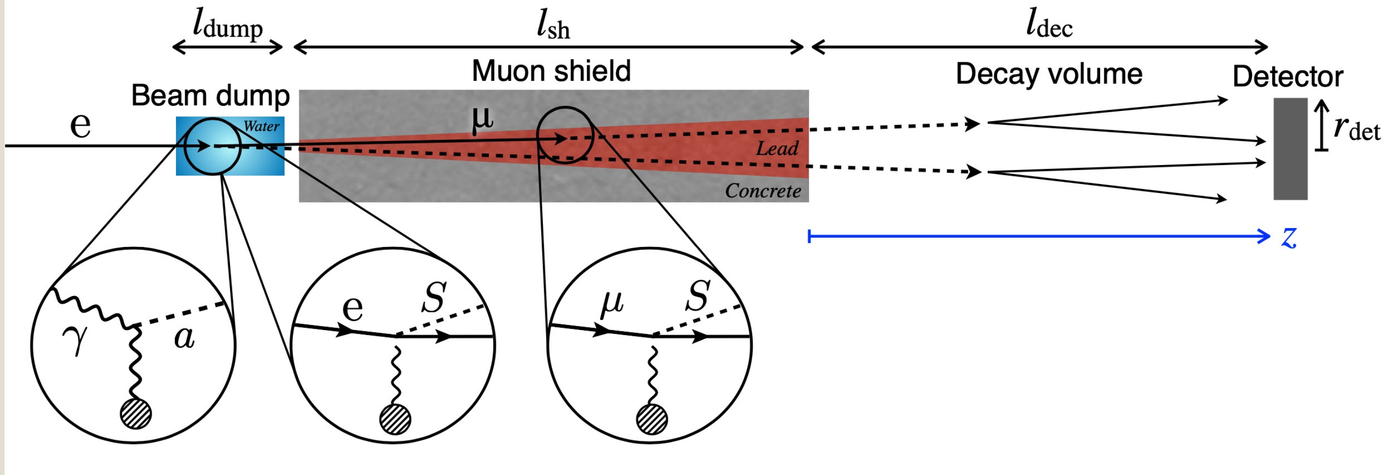


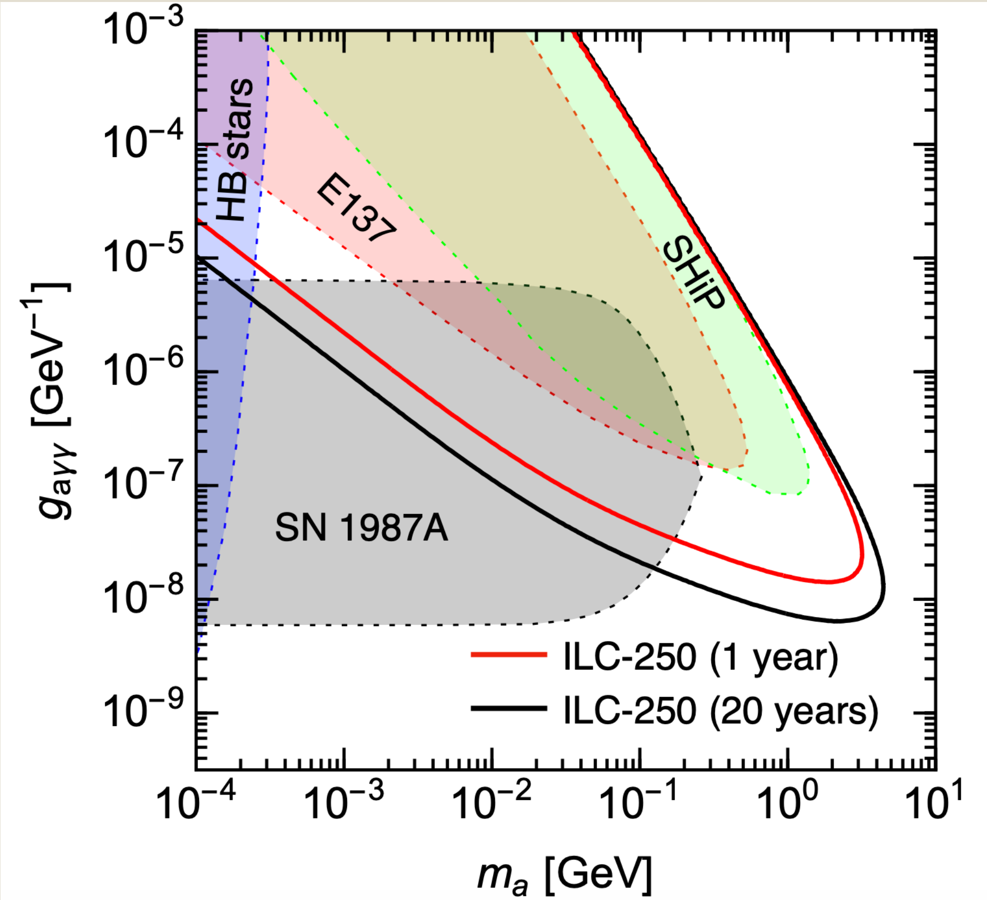
Figure 5: Contours of $N_a = 3$ ALPs with $m_a = 300$ MeV decaying within various ILC detectors, as a function of the production cross section, σ, and the proper lifetime, $c\tau_a$. Shown are the production channels $e^+e^- \to a\gamma$ (left) and $e^+e^- \to Z\gamma \to (a\gamma)\gamma$ (right) at $\sqrt{s} = 250$ GeV and with $\mathcal{L} = 250\ \text{fb}^{-1}$. Predictions are made for the ILD (blue, plain) and far detectors placed in the Shaft (green, dotted), in the Tunnel (red, dot-dashed) and on the Ground (orange, dotted). The branching ratio of the ALP into muons is indicated by $\mathcal{B}_\mu$.

Beam Dump

ALP & new scalar @ E_{beam} =125 GeV

[2009.13790, Yasuhito Sakaki, Daiki Ueda, Searching for new light particles at the international linear collider main beam dump]





Beam Dump

Leptophilic gauge bosons: $e^{\pm}N \rightarrow e^{\pm}N'X$ @ E_{beam} =125, 250, 500 GeV

[**2104.00888, Kento Asai, Takeo Moroi and Atsuya Niki**, Leptophilic Gauge Bosons at ILC Beam Dump Experiment]

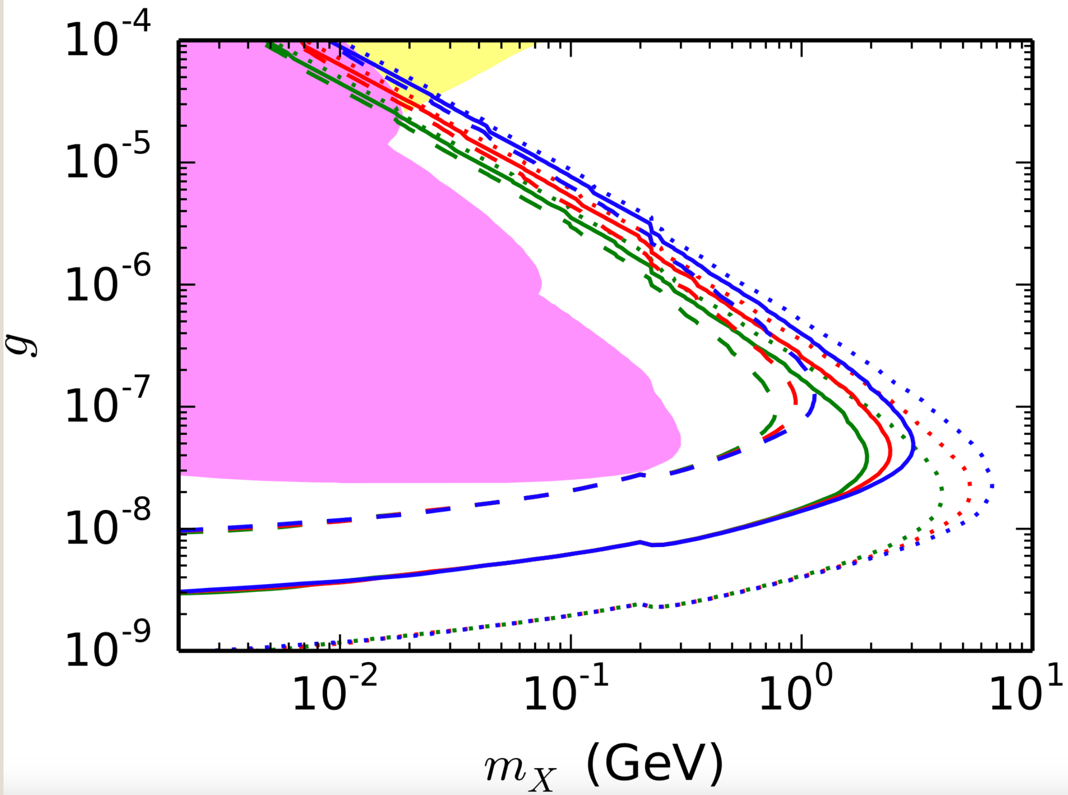


Figure 1: Contours of expected number of signal events for the $U(1)_{e-\mu}$ model. The beam energy is taken to be $E_{\text{beam}} = 125$ (green), 250 (red), and 500 GeV (blue). The dotted, solid, and dashed lines are for $N_{\text{sig}} = 10^{-2}$, 1, and 10^2, respectively, taking $N_e = 4 \times 10^{21}$. The mixing parameter is taken to be $\kappa_\epsilon = 1$. The pink and yellow shaded regions are excluded by beam dump and neutrino-electron scattering experiments, respectively.

Beam Dump

New neutral gauge boson Z' @ E_{beam} =125 GeV

[**2206.12676, Kento Asai, Arindam Das, Jinmian Li, Takaaki Nomura and Osamu Seto**, Chiral Z' in FASER, FASER2, DUNE, and ILC beam dump experiments]

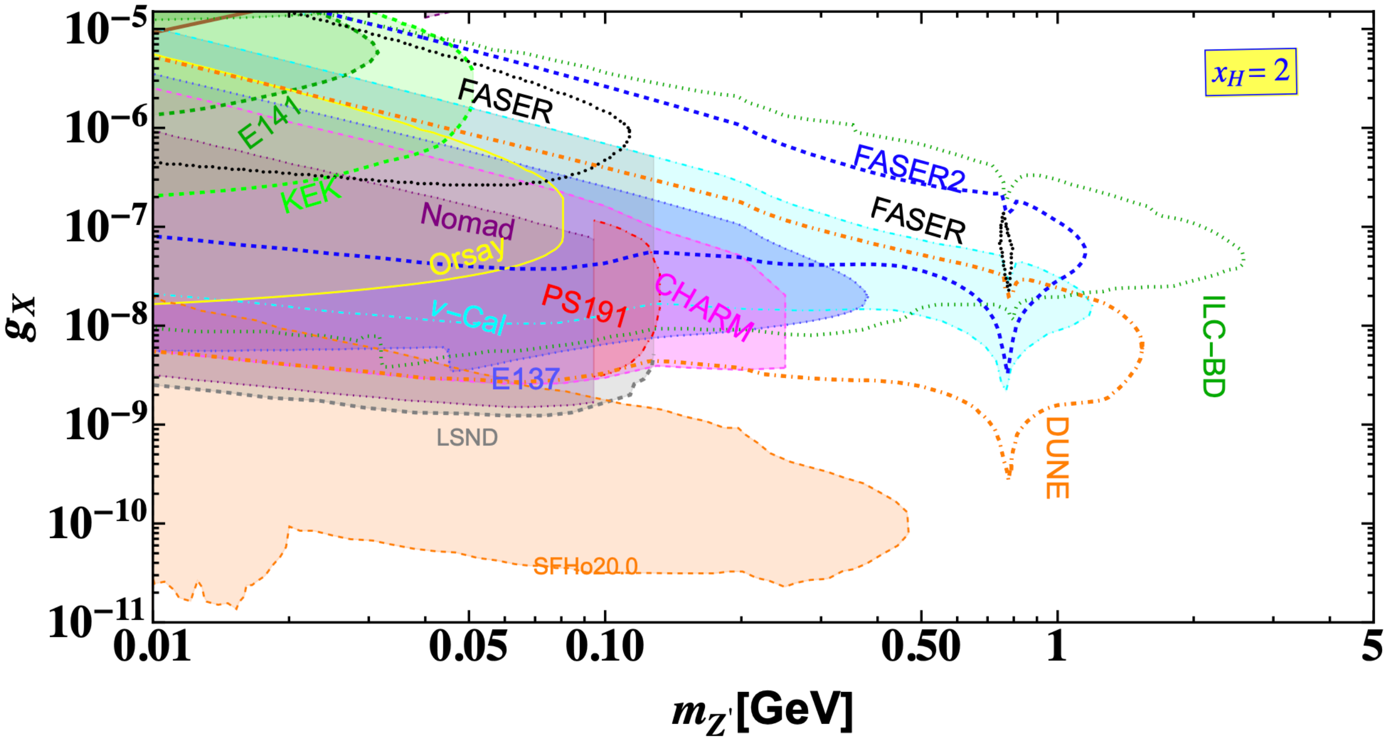


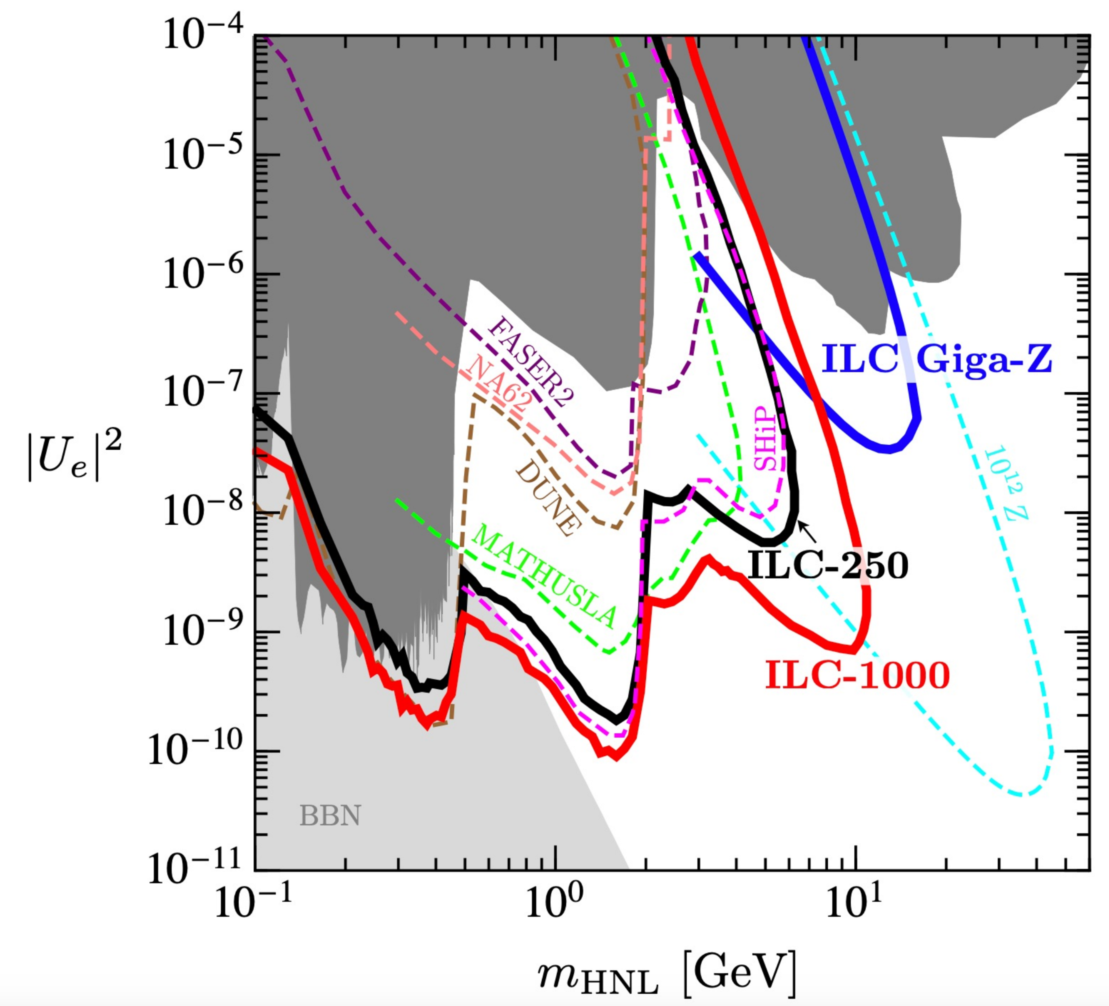
FIG. 6. Limits on $g_X - m_{Z'}$ plane for $x_H > 0$ and $x_\Phi = 1$ considering 10 MeV $\leq m_{Z'} \leq$ 5 GeV showing the regions could be probed by FASER, FASER2, ILC-Beam dump, and DUNE. We compare the parameter space with existing bounds from different beam dump experiments and a cosmological observation of supernova SN1987A (SFH020.0), respectively.

Z' are mainly produced:
the bremsstrahlung process;
rare decay of π_0 and η mesons;
pair annihilation.

Beam Dump

HNL @ E_{beam} = 45.6,125, 500 GeV

[**2206.13523, Mihoko M. Nojiri, Yasuhito Sakaki, Kohsaku Tobioka, and Daiki Ueda**, First evaluation of meson and τ lepton spectra and search for heavy neutral leptons at ILC beam dump]



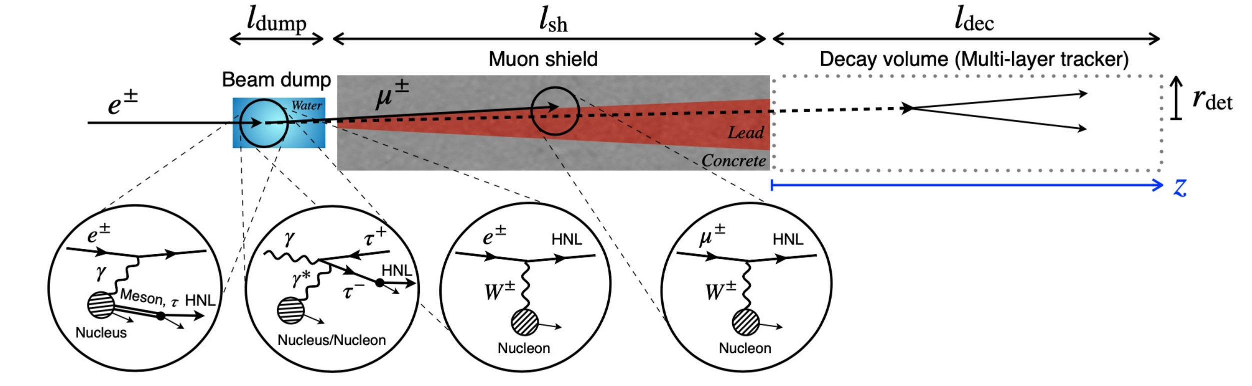


Figure 1. A setup for ILC beam dump experiments. It consists of the main beam dump, a muon shield, and a decay volume. We assume a multi-layer tracker is placed in the decay volume so that the charged tracks are measured.

Figure 5. Sensitivity reach of ILC beam dump experiment to HNLs mixing with the electron neutrino in the mass and mixing plane, assuming 10 year run at ILC-250 (black solid) and ILC-1000 (red solid). The number signal events more than 5.5 (9.1) is required at ILC-250(1000), which corresponds to the 95% C.L. sensitivity. The discussion about the background is in Sec. 4.1. The current exclusion bounds are shown in the gray region, see Sec. 4.3. The darker grey region is from the laboratory bounds, and the lighter gray region is the BBN bound for the HNL, which is roughly $\tau_{HNL} > 0.02$ s [30]. Sensitivity reach through 10^9 Z-decays at ILC is shown as a blue solid line. See Sec. 4.2. For a comparison, dashed lines show a sensitivity reach of the DUNE experiment [40] (brown), the FASER2 experiment [41] (purple), the NA62 experiment [1] (orange), and the SHiP experiment [8] (magenta), the MATHUSLA experiment[42] (green), and 10^{12} Z-decays that could be realized at the FCC-ee experiment (cyan).

Discussion

LLPs searches @ ee colliders have **unique characteristics** (high lum., clean environment, EW prod., transverse direction, recoil strategy) and are important ways to BSM physics.

Studies with Near Detectors

→ Higgs/Z decays, new scalars, dark photon, mirror glueballs

→ HNL, ALP, SUSY, hidden valley particles, ...

Studies with Far Detectors

→ Higgs decays, HNL, SUSY, ALP, ...

Studies with beam dump

→ ALP, new scalars, HNL, leptophilic gauge bosons, Z', ...

More studies are very welcome!

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CEPC New Physics and Flavor Physics Workshop
Time: August 13 to 17, 2023
Place: Fudan University, Shanghai, China
Webpage: https://indico.ihep.ac.cn/event/19839/

Goals:
(1) to facilitate discussions in New Physics and Flavor Physics studies at CEPC;
(2) to promote the preparation of the CEPC Physics White Paper;
(3) to delve into the detector requirements and relevant key technologies.

You are very welcome to register and attend this workshop !
Please contact me if you want to add your LLP studies to the upcoming CEPC Physics White Paper !