*CEPC New Physics Workshop 2024*

# CEPC WP discussion —— supersymmetry

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# Overview

- **SUSY search @ CEPC can be complementary in covering parameter spaces that are difficult for the LHC to reach. Comparing to LHC, CEPC has**
  - **Well-defined energy, momentum and polarization**
  - **High-precision measurements**
  - **Clean environment**
  - **A minor dependence on the reconstruction model and detector geometry**
  - **Superior sensitivity for electroweak stats, especially in probing super soft/ compressed scenarios**

VII. Supersymmetry (Tianjun, Lei, Xuai, Da)

A. Light electroweakino searches

B. Light slepton searches

C. Input from the European Strategy

- **6 analyses + EU input**

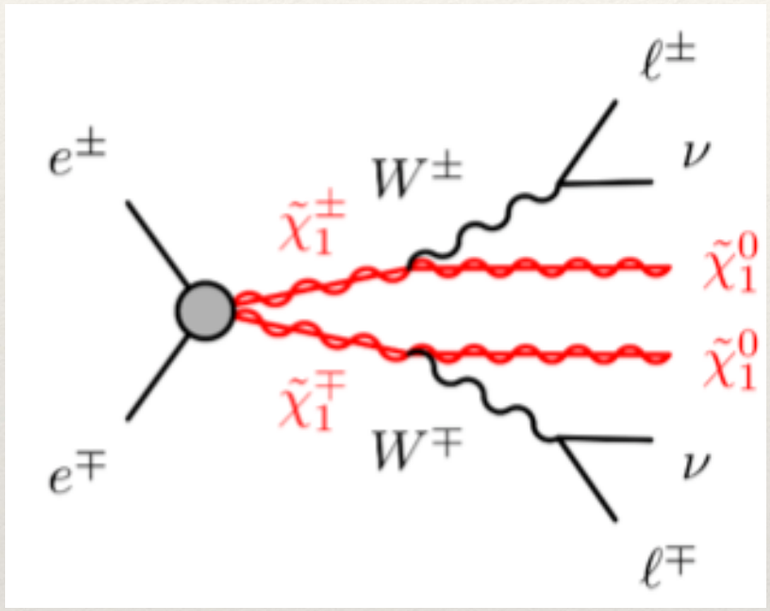
*Higgsino/Bino-NLSP*

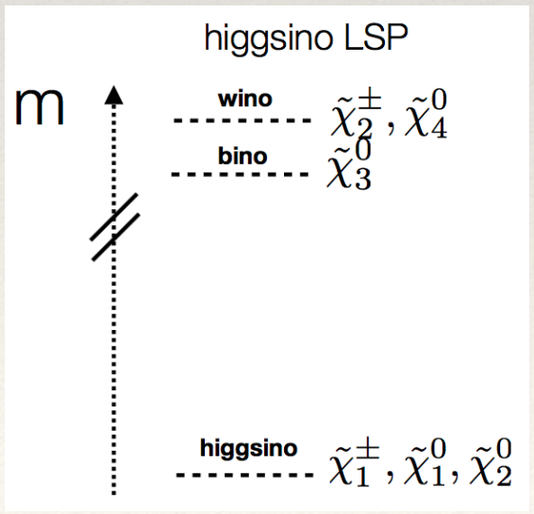
*Smuon-stau/Right-handed off-shell selectron/ Off-shell Smuon/Right-Handed Slepton with DM*

- **A novel/ongoing analysis on quantum entanglement in SUSY production & decay: expected to come by the end of the year; large possibility to catch up the white paper!**

# Higgsino search

- **Light Higgsinos, well-motivated by naturalness, tend to have small mass splitting; challenge to probe at LHC**



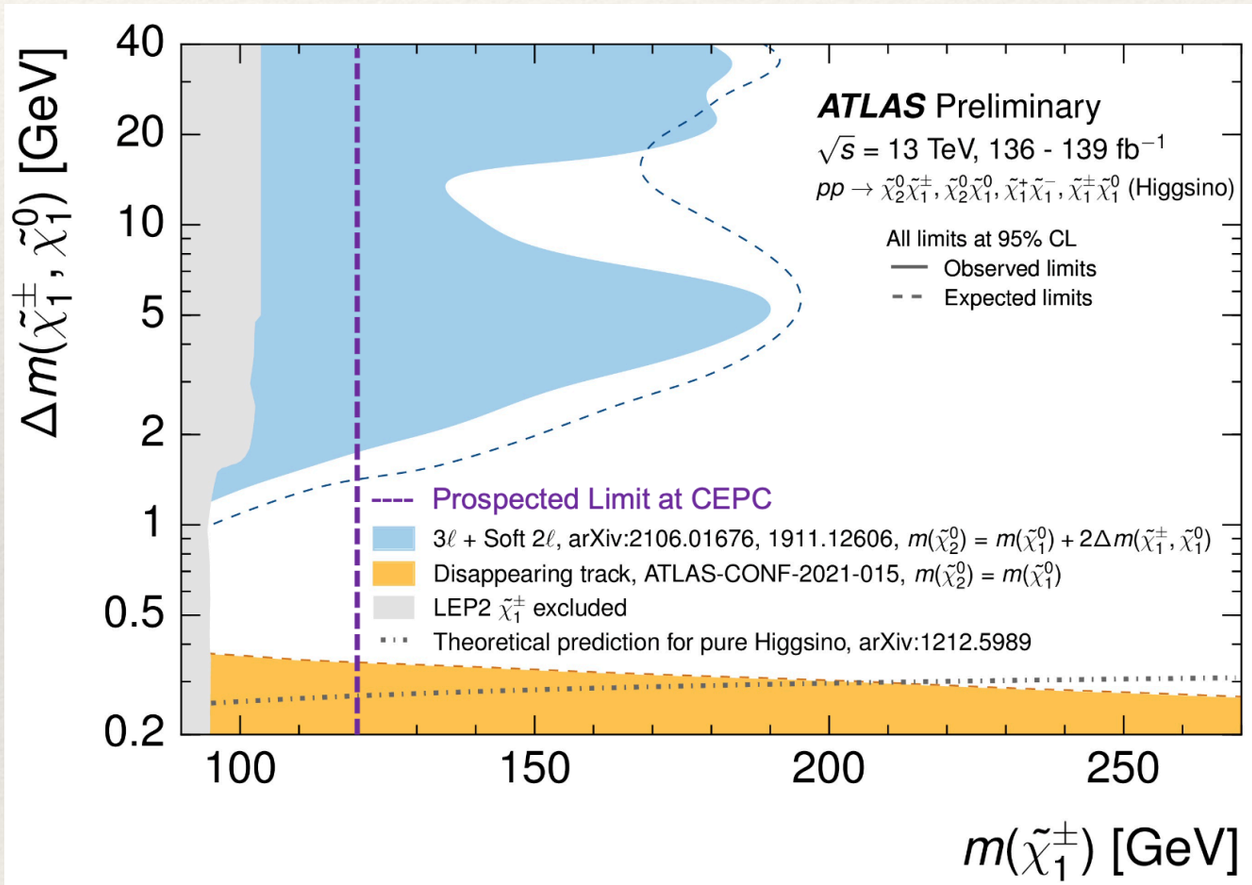
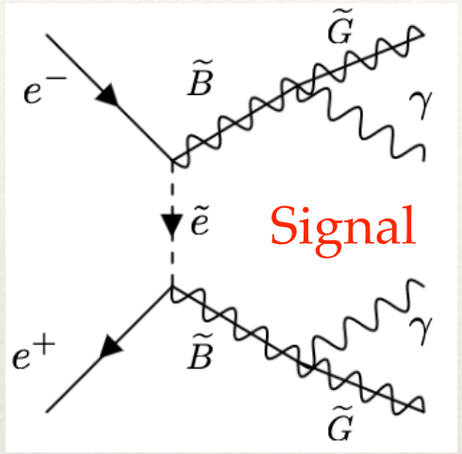
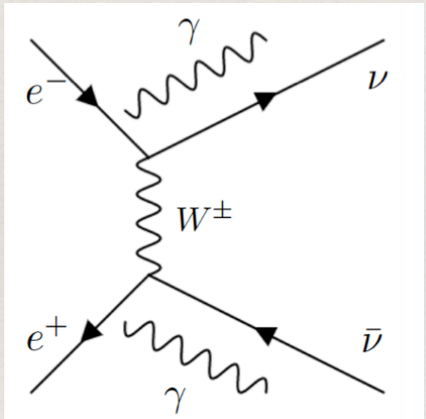
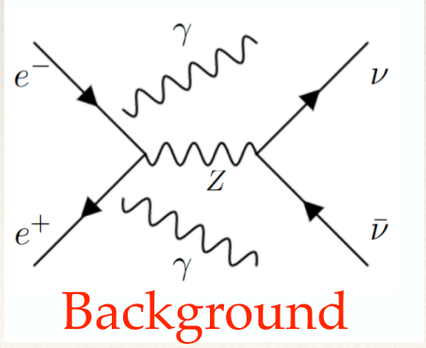




FIG. 51: The observed and expected exclusion limits on simplified SUSY models for chargino-pair production with Higgsino-like LSP obtained by the ATLAS. The observed limits obtained by the LEP are shown in light grey. The prospected limits at the CEPC are also shown in the dotted purple line for rough comparison.

# Bino-NLSP




- Light bino motivated by GMSB; Gravitino as LSP and bino as NLSP
- Bino pair production via t-channel; Scenario with 2photons+missing energy; SM t-channel W, s-channel Z as main background
- CEPC can exclude selectron lighter than 4.5 TeV (2 TeV) with bino mass around 10 GeV (100 GeV)

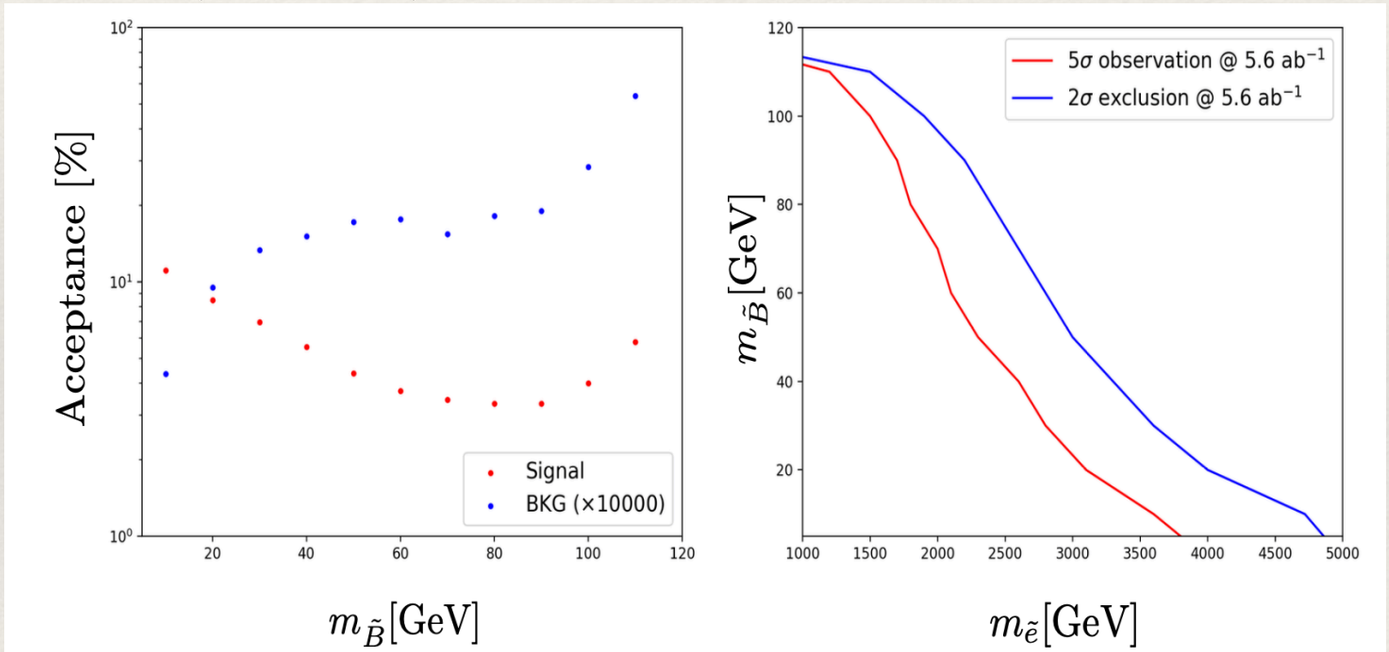
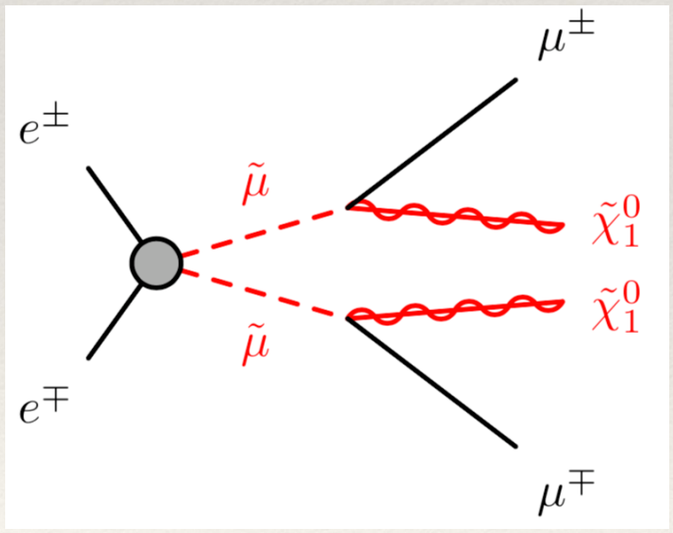



FIG. 52: *Left*: acceptance of signal and background processes as functions of $m_{\tilde{B}}$. Here the acceptance of the background process has been multiplied by 10,000. *Right*: $2\sigma$ exclusion and $5\sigma$ observation limits on the $m_{\tilde{e}} - m_{\tilde{B}}$ plane at a future lepton collider running with an integral luminosity 5.6 ab$^{-1}$ and center-of-mass energy 240 GeV. Regions below the red (blue) curves are observable (excluded).

arxiv:2203.10580

# Smuon/stau search

- Smuon(stau) is favored by muon g-2 excess; soft sleptons are difficult in LHC
- At 240 GeV, assuming a flat 5% uncertainty, the discovery sensitivity can reach up to 117 (116) GeV for smuon (stau) mass via direct smuon (stau) production, filling a significant region in the gap in the LHC search. Studies at 360 GeV also provided



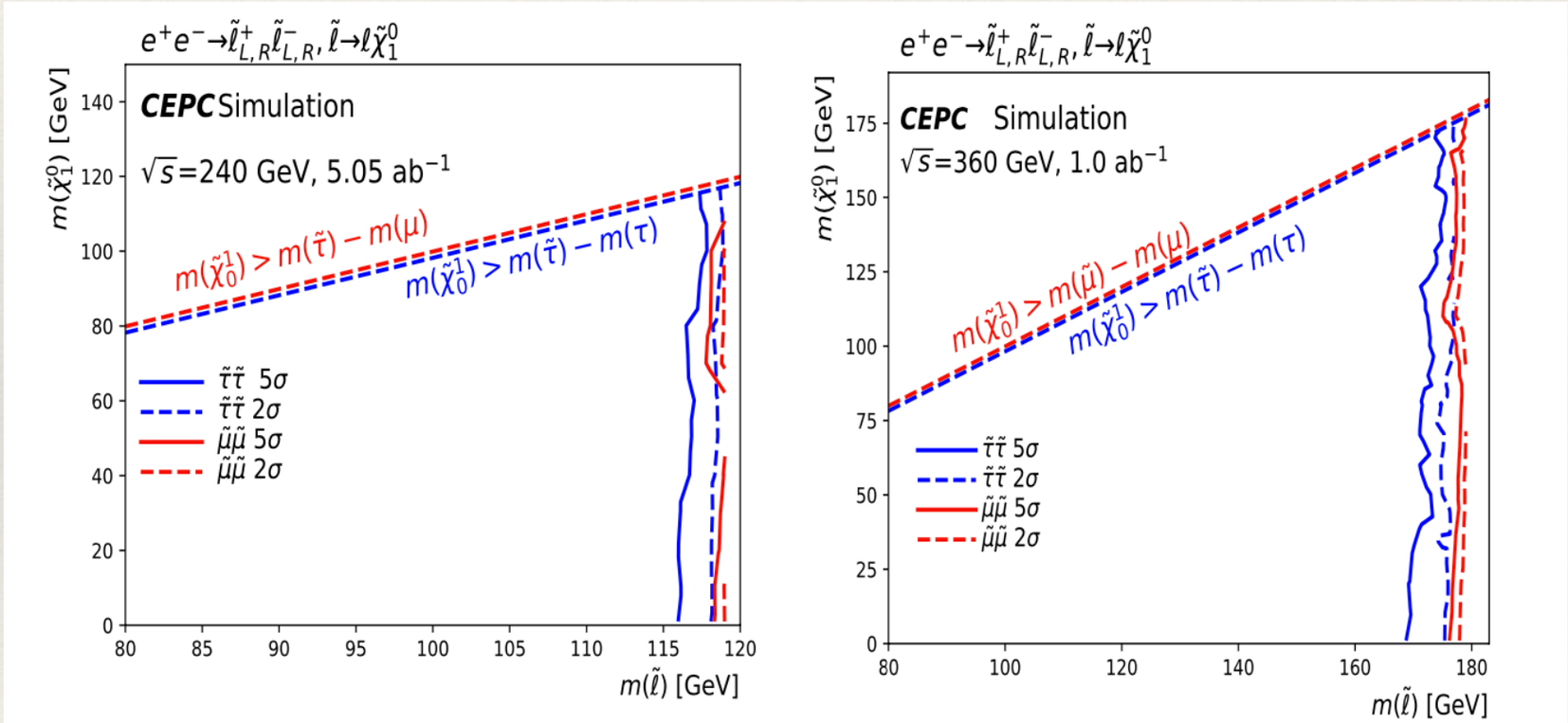
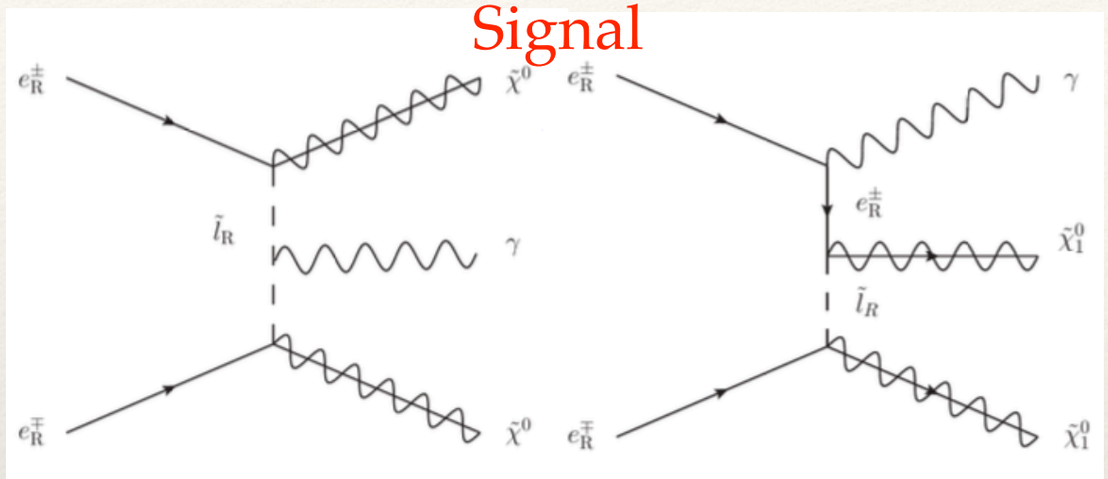




FIG. 53: The $5\sigma$ discovery contour (solid line) and $2\sigma$ exclusion contour (dashed line) for the direct stau production and direct smuon production with 5% flat systematic uncertainty. Left (Right) plot presents the center-of-mass energy of 240 (360) GeV.

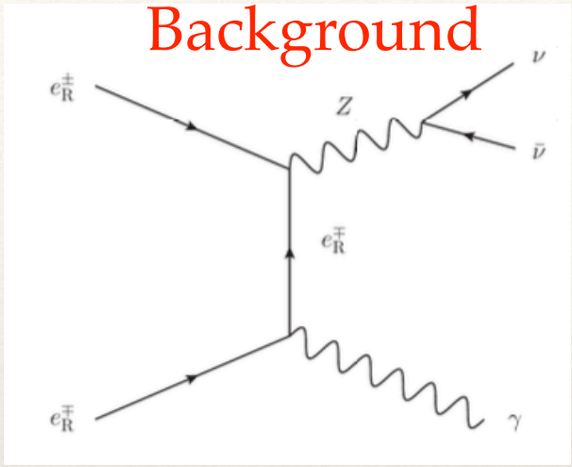
arxiv:2202.11011

# Right-handed *off-shell* selector

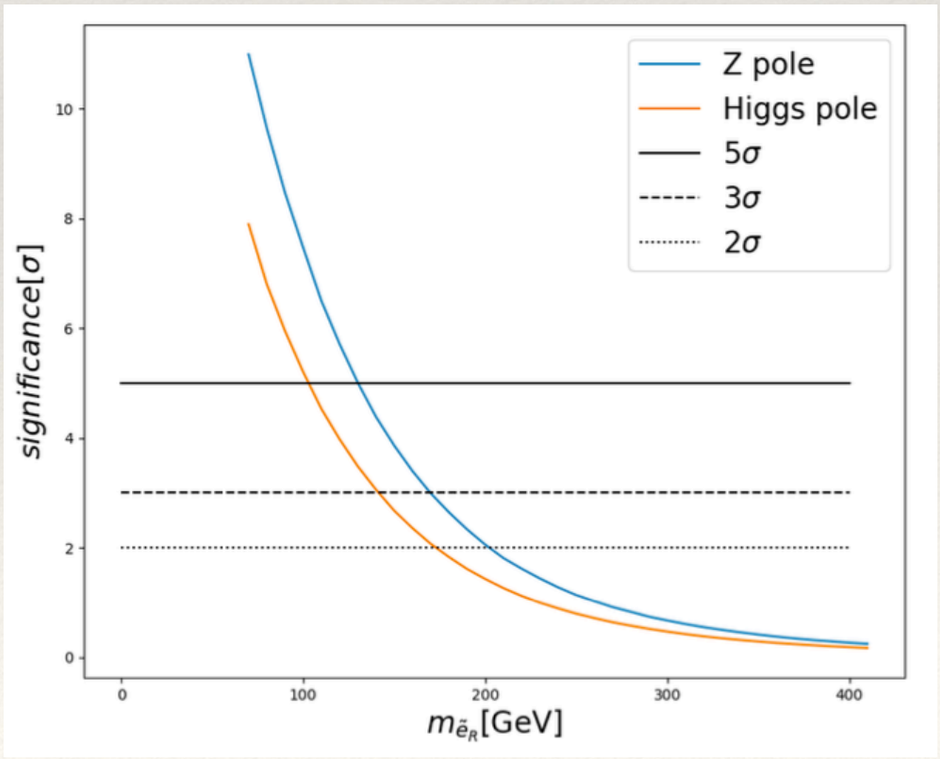
Signal




Background

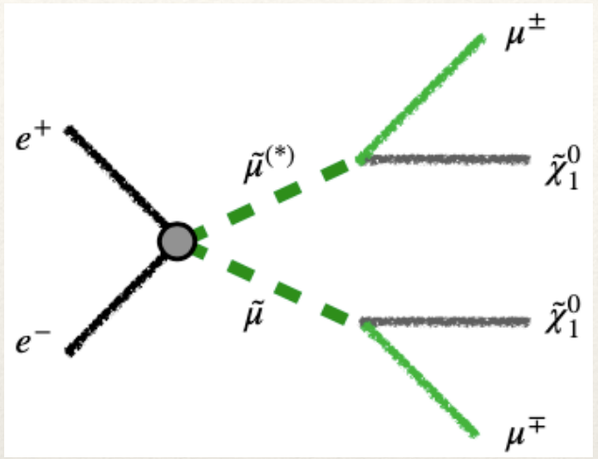



- Search for $e_R^+ e_R^- \rightarrow \tilde{\chi}_1^0$(bino) + $\tilde{\chi}_1^0$(bino) + $\gamma$ with t-channel process mediated by an off-shell right-handed slepton
- The reach depends on the model assumptions.
  - If LSP annihilating through the Z-pole, the right-handed selectron can be excluded up to 180 (210) GeV respectively at 3(2)σ
  - If the annihilation through the Higgs pole dominates, right-handed selectron will be excluded up to 140 (180) GeV at 3(2)σ



arxiv:2211.08132

# *Off-shell* Smuon




- Off-shell smuon pair production at the CEPC
- Assuming a flat 5% uncertainty, the detection (discovery) sensitivity can reach up to 126 GeV (122 GeV) for the smuon mass, breaking through the limits of the on-shell kinematic limit of $\sqrt{s}/2$ and enter the off-shell region in detecting new physical processes

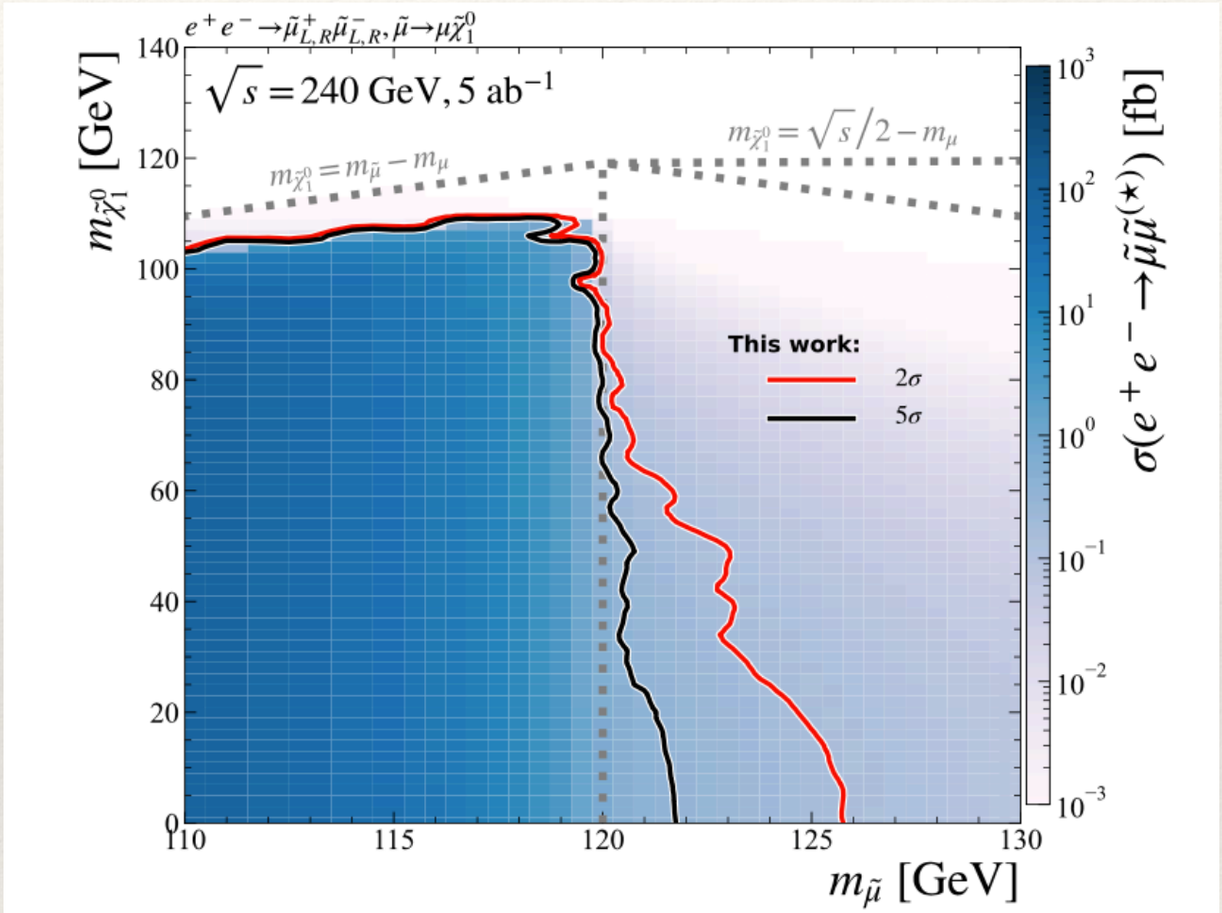



FIG. 54: The prospected exclusion contour and discovery contour at CEPC for the direct smuon production with 5% flat systematic uncertainty.

# Right-Handed Slepton Bulk Region for DM

- A light right-handed slepton bulk region is realized in F -S U (5) and the pMSSM
- Comprehensive numerical studies with experimental constraints show that $R_\phi \gtrsim 10\%$ is a conservative criterion to formulate the bulk region
- If the Bino contributes all the DM abundance, the ratio $R_{\tilde{\tau}_1} \gtrsim 10\%$ implies $m_{\tilde{\chi}^0_1} \leq 103.0$ GeV
- The upper limits on the $\tilde{\tau}$ and $\tilde{e}$ masses are around 115 GeV and 150 GeV, respectively. These light sleptons could conceivably be observed at lepton colliders

$$\mathcal{R}_\phi \equiv (m_\phi - m_{\tilde{\chi}_1^0})/m_{\tilde{\chi}_1^0}$$

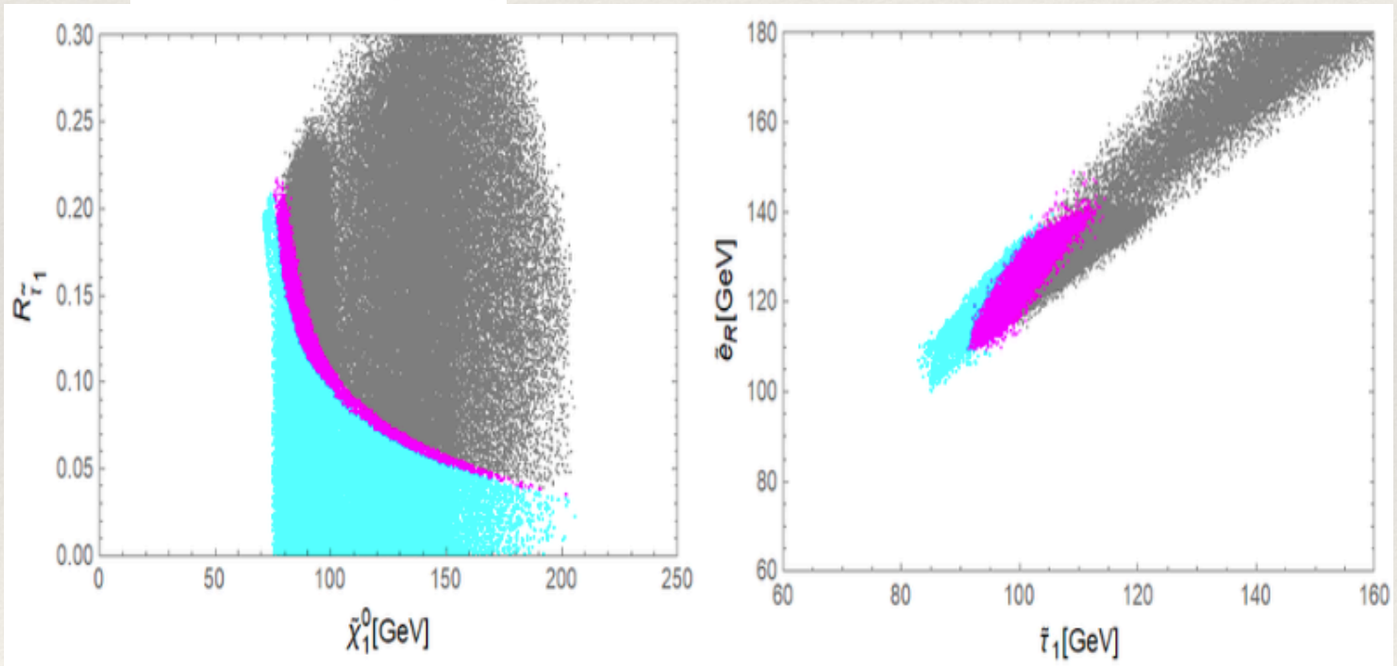



FIG. 55: Left: Bulk region in Generalized No-Scale $\mathcal{F}$-$SU(5)$. Right: Light right-handed slepton masses in this bulk region. Cyan, magenta, and gray points correspond to under-saturated, saturated, and over-saturated DM relic density.

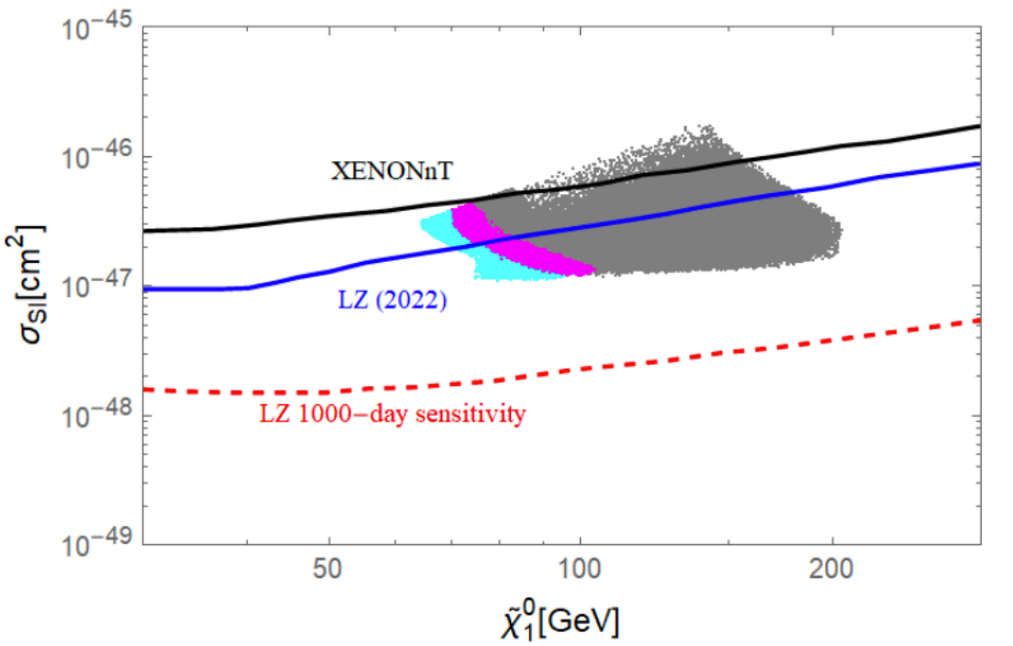
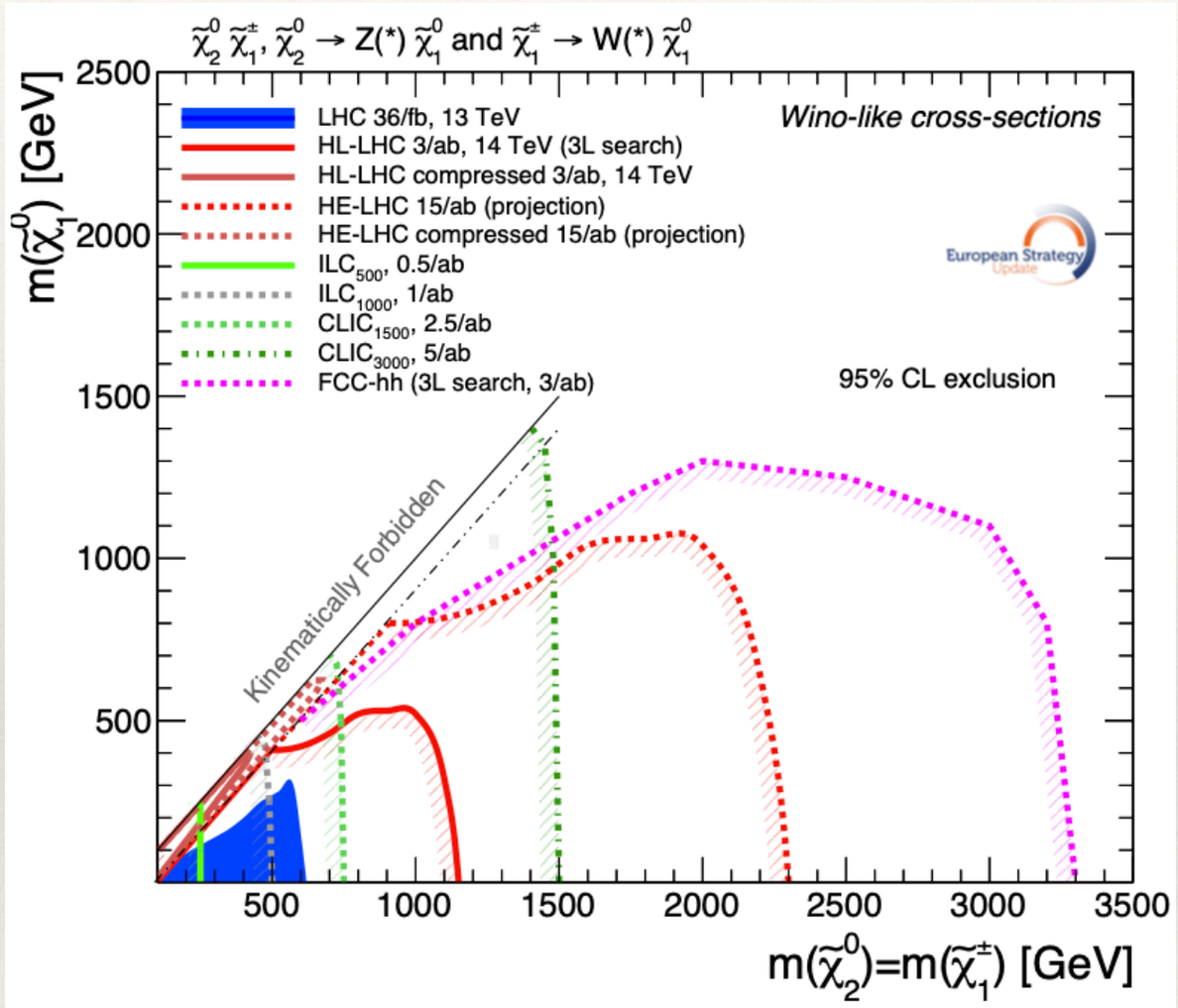
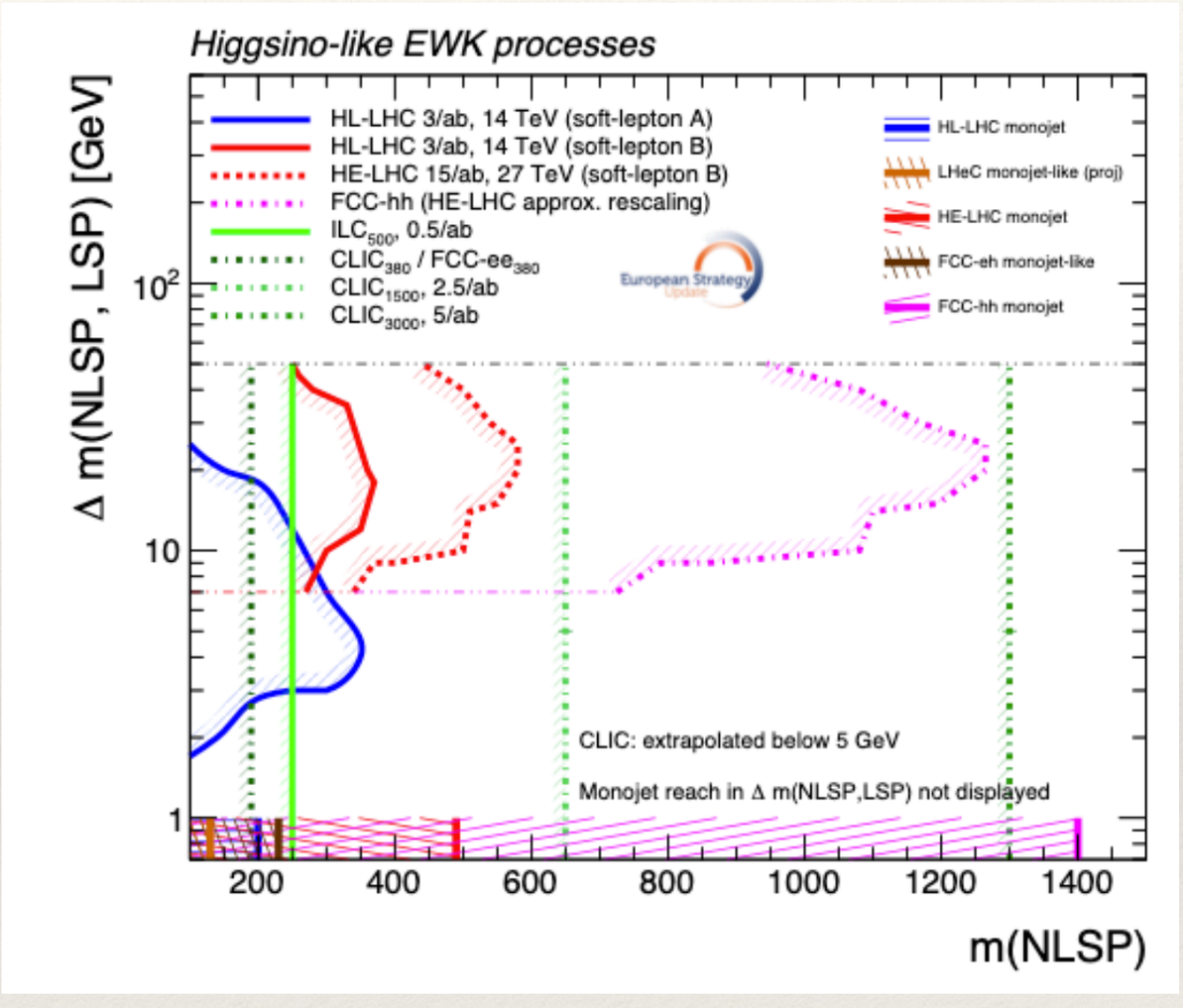



FIG. 56: The spin-independent DM-nuclei cross sections vs the LSP mass in the Generalized No-Scale $\mathcal{F}$-$SU(5)$ bulk region. We present the constraints from the XENONnT [349] and LUX-ZEPLIN [348, 350] experiments. We underscore the significance of the 1000-day LUX-ZEPLIN run that should fully probe the $\mathcal{F}$-$SU(5)$ bulk and about 50% of the pMSSM bulk (not shown here). The color code is the same as in FIG. 55.

# Input from the European Strategy




- **In the compressed scenario, lepton colliders analyses are competitive to hadron colliders: sensitivity up to electroweakino masses equal to $\sqrt{s}/2$ are possible even for $\Delta m(\tilde{\chi}^{\pm}_1,\tilde{\chi}^{0}_1)$ as low as 1 GeV, with no loss in acceptance (ILC and CLIC)**

# Extra slides