Electroweakino and slepton search summary in ATLAS

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1st, Nov, 2025

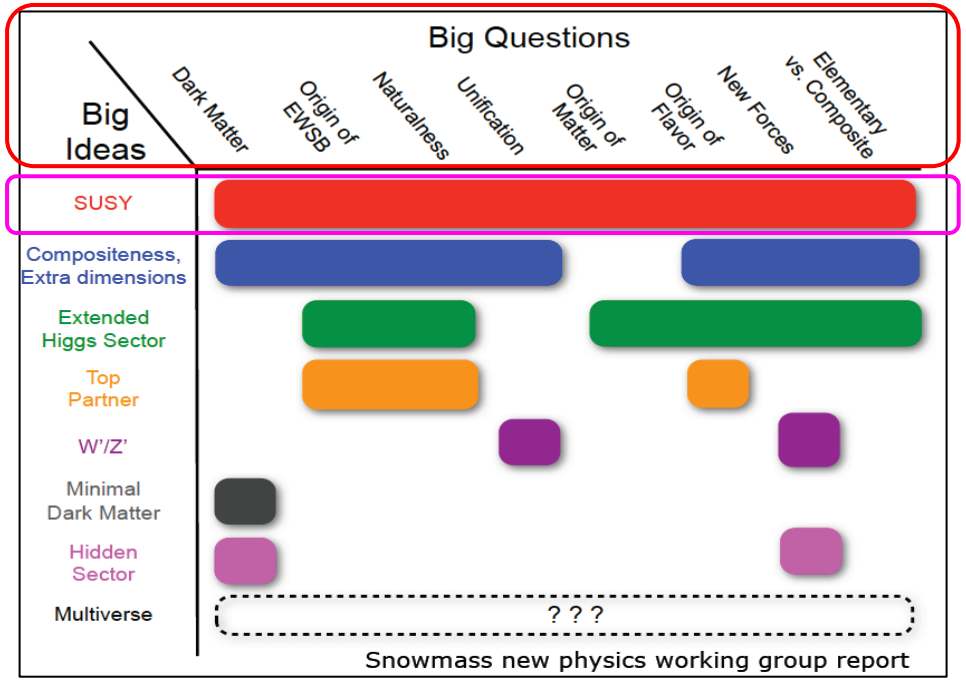
SUSY

The Standard Model (SM) is the most accurate and successful description of fundamental particles and their interactions

- **However, it leaves several big questions to be solved**
  - Hierarchy Problem
  - Dark matter
  - Unification of Forces
  - Cosmological Asymmetry

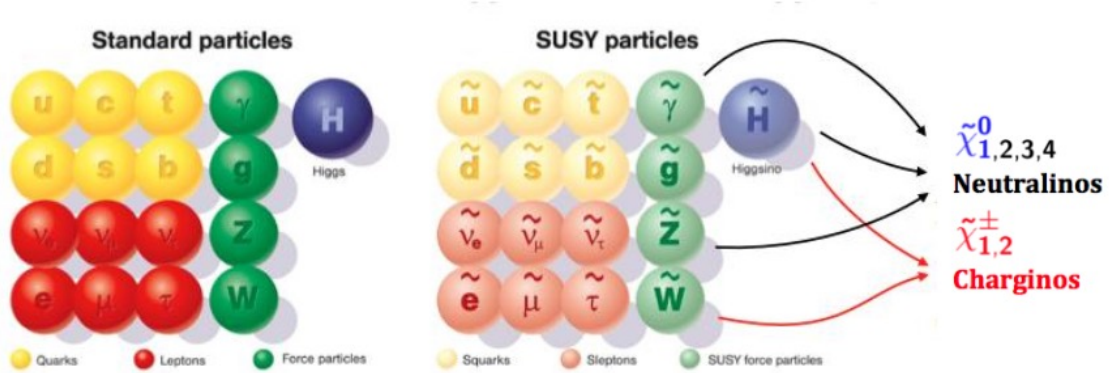
➢ **Motivating searches for physics beyond the Standard Model (BSM)**

- **SUSY** provides solution for most of the big questions



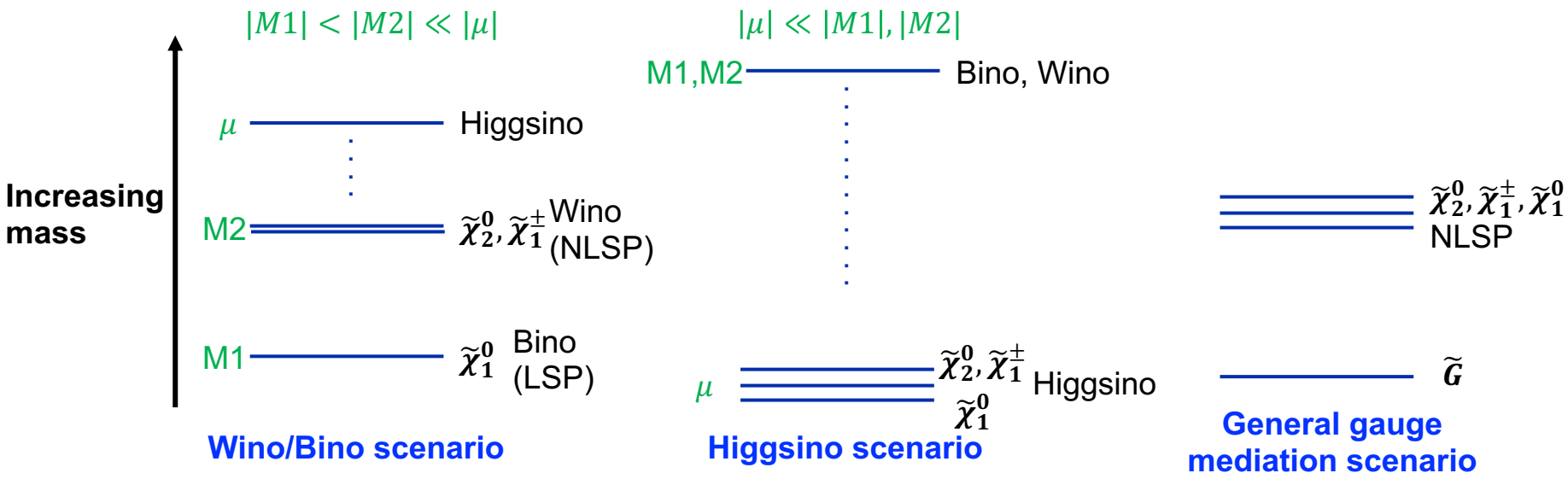
A superpartner of each SM particle with spin differing by ½

- Leptons and neutrinos have **sleptons** $\tilde{\ell}$ and **sneutrinos** $\tilde{\nu}$
- Partners to $W^{\pm,0}$ and B bosons are **winos** $\widetilde{W}$ and **binos** $\widetilde{B}$, partners to Higgs are **higgsinos** $\widetilde{H}$
  - Mix and form **charginos** $\tilde{\chi}^{\pm}_{1,2}$ and **neutralinos** $\tilde{\chi}^{0}_{1-4}$



Electroweak SUSY

- **Progressively stringent constraints on strong-production SUSY** (upper limits on masses up to ~ TeV)
  - **Electroweak-production SUSY** are **key analyses** to search for SUSY
- Wino, Bino, Higgsino mixing → **2 charginos** $\tilde{\chi}_i^{\pm}$ + **4 neutralinos** $\tilde{\chi}_i^0$ → different possible mass spectrum in different scenarios

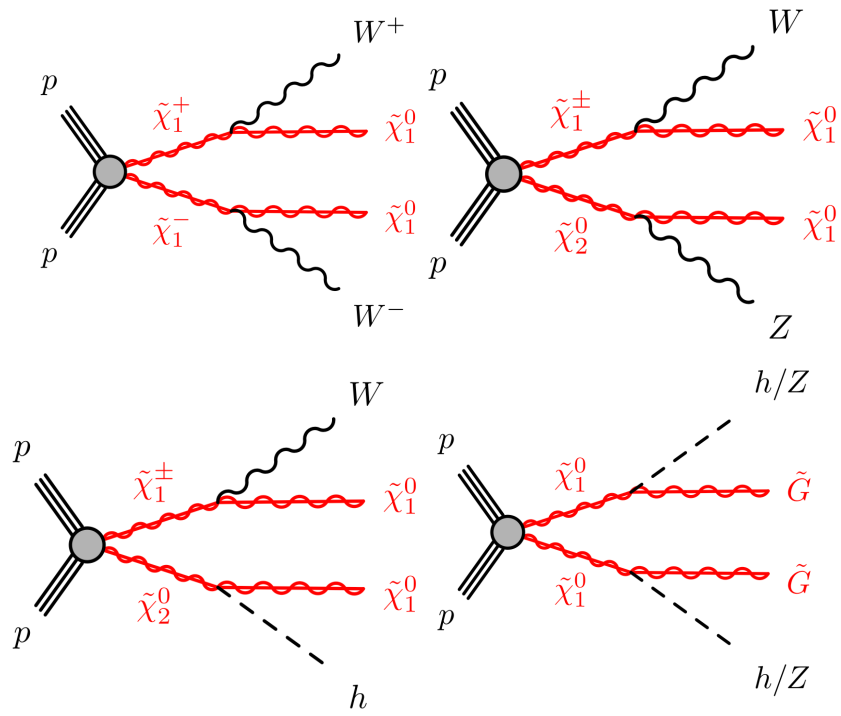


Combination of Electroweakino Searches

PHYSICAL REVIEW LETTERS 133, 031802 (2024)

NEW

- Signal model
  - **Electroweakino production**
  - **Wino/bino scenario and GGM scenario**
  - decay via **W, Z, h**
- Statistical combination
  - Overlap between searches
    - avoided for most part by **lepton multiplicity**
    - If searches overlap, the search with **the best expected sensitivity** is used.
  - Systematic uncertainty
    - **Experimental uncertainties** are **correlated** between CRs and SRs with common nuisance parameters
    - **Theoretical uncertainties** are **uncorrelated** since searches target at different final states and parameter space

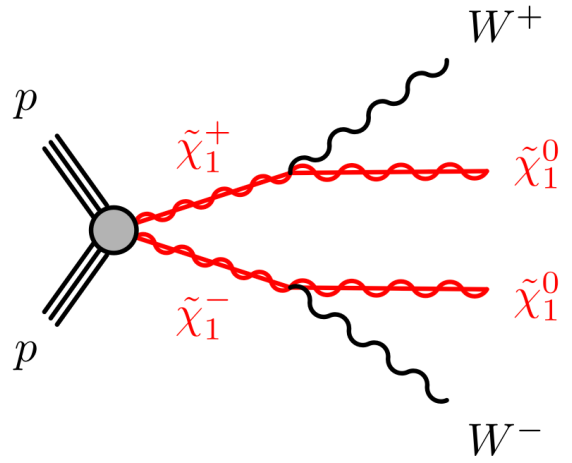


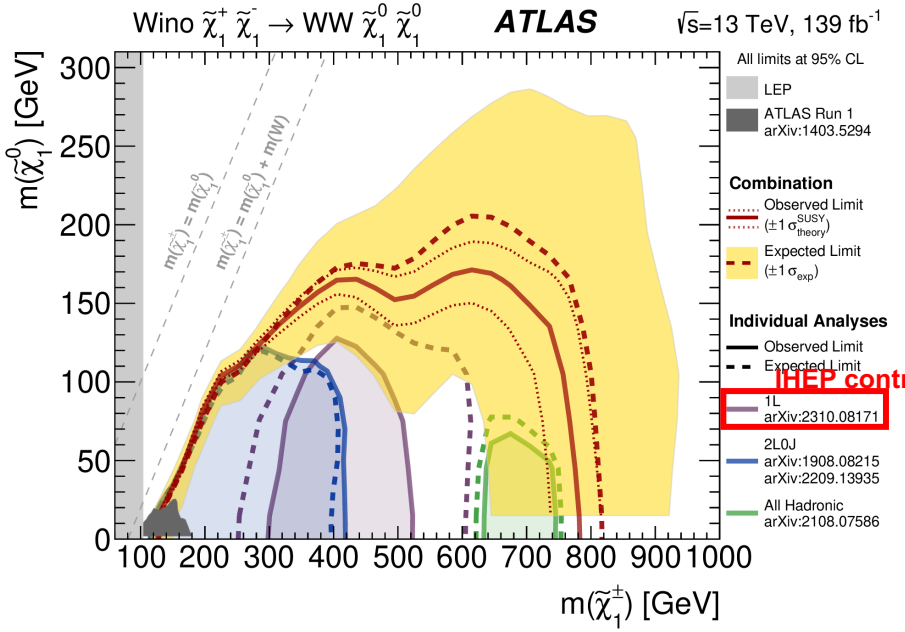
Combination of Electroweakino Searches

PHYSICAL REVIEW LETTERS 133, 031802 (2024)

NEW

- Signal model: wino-bino scenario
  - **Pure-wino $\tilde{\chi}_1^+\tilde{\chi}_1^-$ production decaying via W**
- Fully leptonic: Two **2L0J searches** overlap, so the one with lowest expected C.L. value is used.
- Semileptonic: **1L search** is statistically independent of other searches
- Fully hadronic: **All Hadronic search** is statistically independent of other searches
- Combination **fills the gap** at $m(\tilde{\chi}_1^0) \sim 600$ **GeV**, **increase sensitivity to high** $m(\tilde{\chi}_1^0)$, and **the upper limit on cross-section is decreased by** $20\% - 30\%$ **for** $m(\tilde{\chi}_1^0) \in [400, 800]$ **GeV**



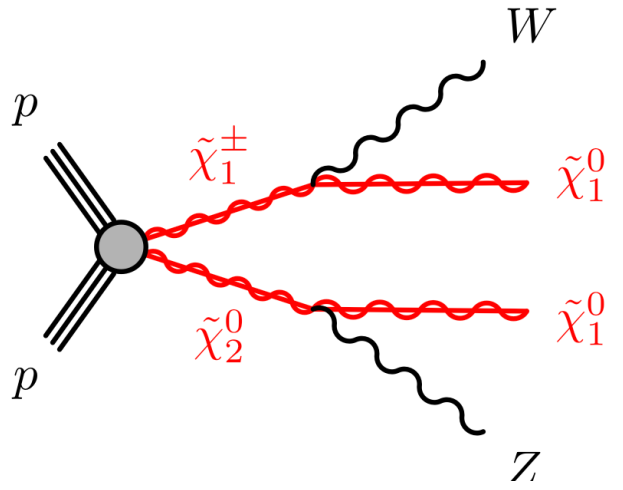


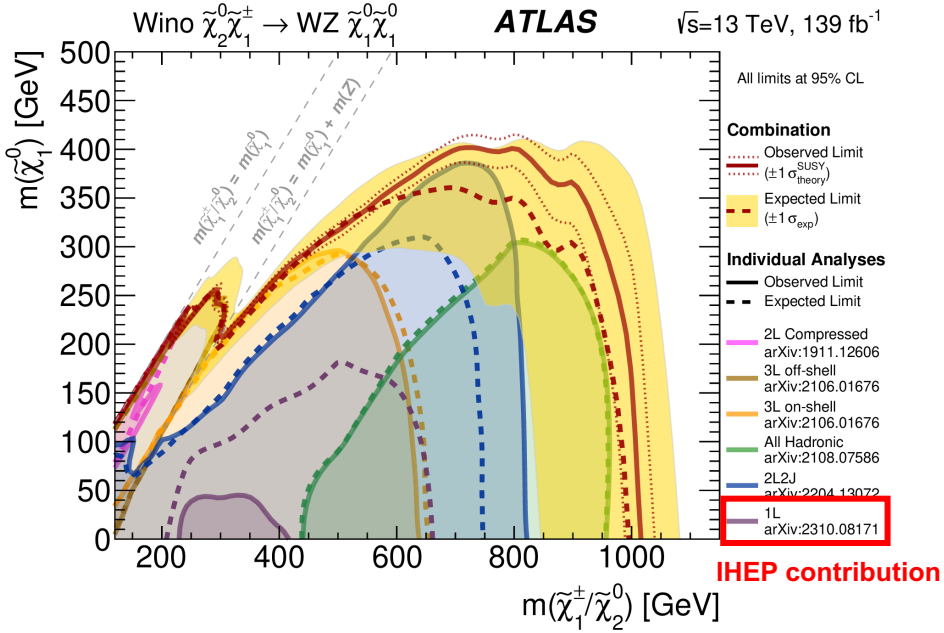
Combination of Electroweakino Searches

PHYSICAL REVIEW LETTERS 133, 031802 (2024)

NEW

- Signal model: wino-bino scenario
  - **Pure-wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production decaying via W, Z**
- All searches are statistically independent: 2L Compressed, 3L, 2L2J, 1L and All Hadronic
- **Extends limits by ~ 50 GeV at high $m(NLSP)$**
- **Extends limits of m(LSP) by $40-100$ GeV at $m(NLSP)$ around 550 GeV and 800 GeV,**
- **Decreases the upper limit on the cross-section by $20\%-40\%$ for NLSP $600-1000$ GeV**



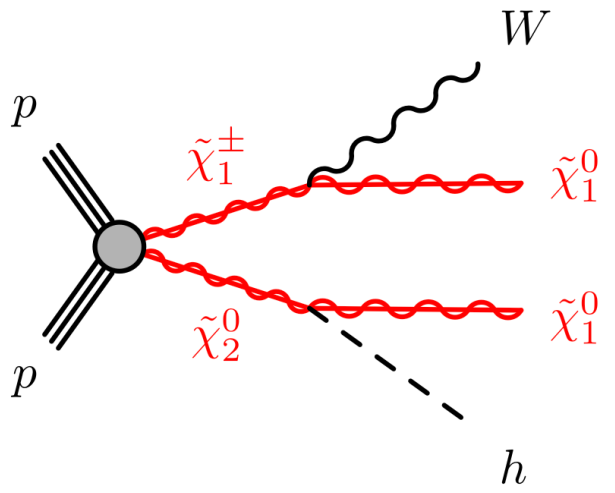


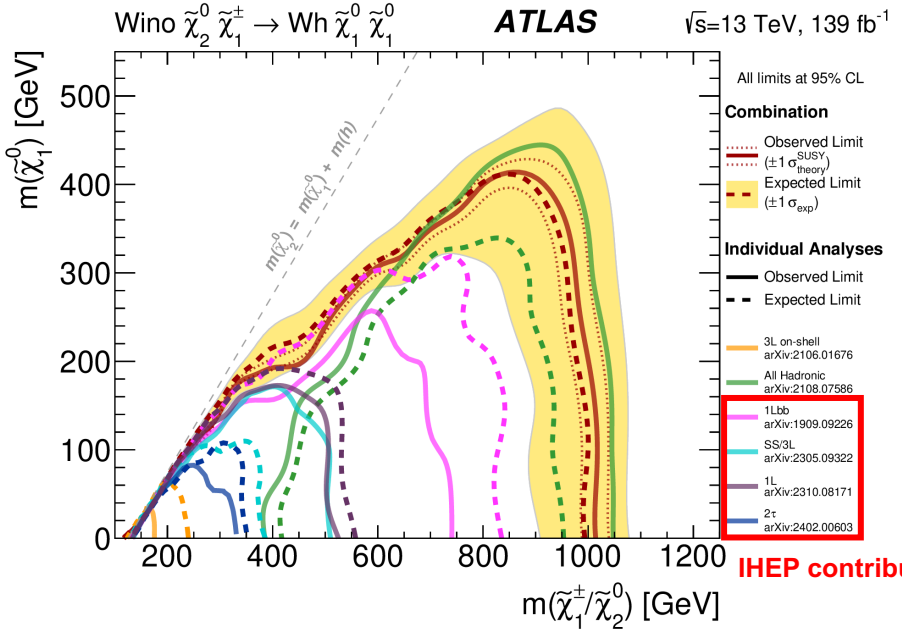
Combination of Electroweakino Searches

PHYSICAL REVIEW LETTERS 133, 031802 (2024)

NEW

- Signal model: wino-bino scenario
  - **Pure-wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production decaying via W, h**
- **All Hadronic** and **1Lbb** searches dominate the sensitivity
- **SS/3L** and **3L** and **2τ** searches are sensitive to low mass NLSP
  - **SS/3L** and **3L** searches overlap, so the one with lowest expected C.L. value is used.
- **Extends limits up to 30 GeV in m(LSP) for m(NLSP) in range of $300 - 600$ GeV**
- **Decreases upper limit on the cross-section by $20\% - 30\%$ for m(NLSP)< 600 GeV**



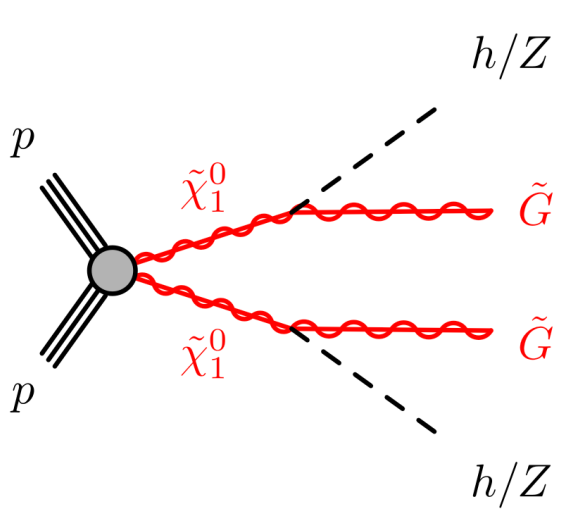


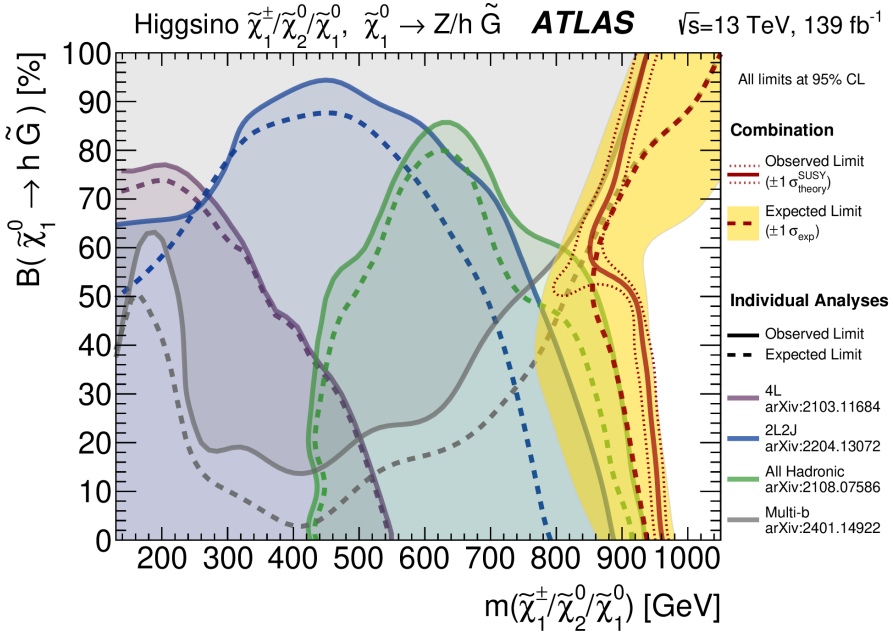
IHEP contribution

Combination of Electroweakino Searches

PHYSICAL REVIEW LETTERS 133, 031802 (2024)

- Signal model: GGM scenario
  - **Pure-higgsino $\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_2^0\tilde{\chi}_1^0, \tilde{\chi}_1^\pm\tilde{\chi}_{1,2}^0$ production decays to $\tilde{\chi}_1^0$, and $\tilde{\chi}_1^0 \to h/Z\,\tilde{G}$**
- 4L, 2L2J, All Hadronic searches targets leptonic or hadronic decays of Z boson
- **Multi-b** search selects $h \to bb$
  - All Hadronic and **Multi-b** are overlap, so the one with lowest expected C.L. value is used.
- **Extends the exclusion by ~60 GeV for high mass Higgsino**
- **The upper limit on the cross section is decreased by $15\% - 40\%$ for $\mathbf{Br}(\tilde{\chi}_1^0 \to h\tilde{\mathbf{G}}) < 80\%$**

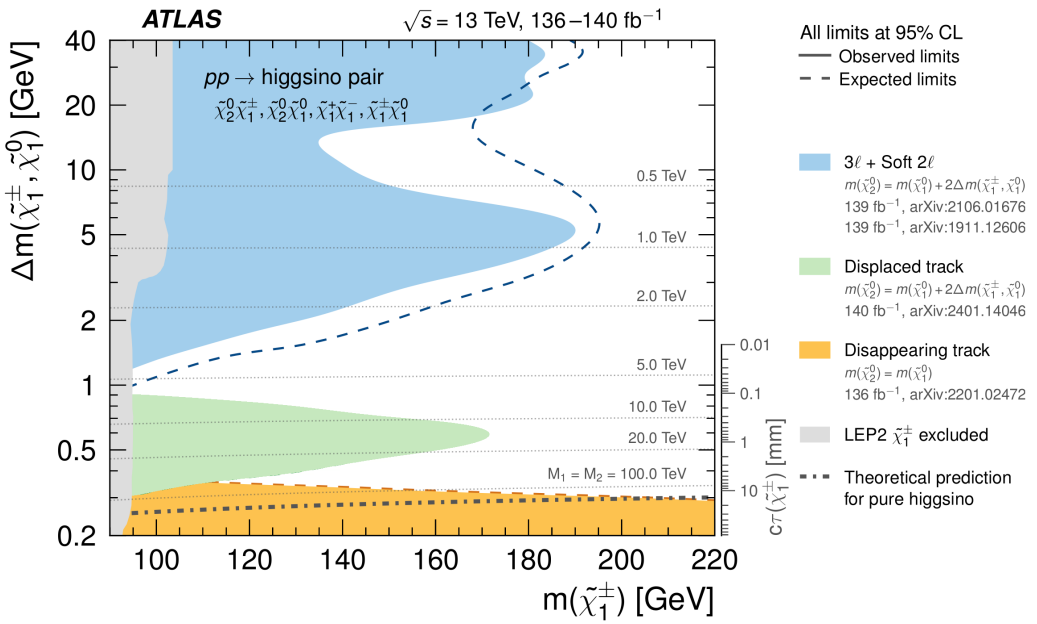


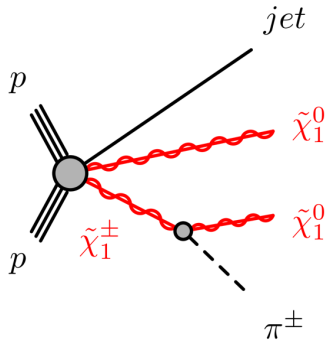


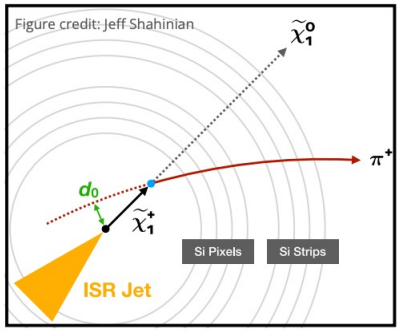
Higgsino Searches

Phys. Rep. 1116 (2025) 261-300

- **Higgsino scenario**
  - Light higgsino → **Hierarchy problem**
  - Naturally **compressed** $\Delta m \sim \mathcal{O}(0.1-50)$ GeV
- The combination of 3L and soft 2L **($\Delta m \sim \mathcal{O}(1-40)$ GeV)**
  - **Exclude up to 180 GeV for $\Delta m \sim 30$ GeV and up to 190 GeV for $\Delta m \sim 5$ GeV**
- Displaced track **($\Delta m < 1$ GeV)**
  - **Exclude up to 170 GeV for 0.3 GeV $< \Delta m < 0.9$ GeV**
- Disappearing track **(smallest Δm)**
  - **Exclude up to 210 GeV for $\Delta m < 0.3$ GeV**







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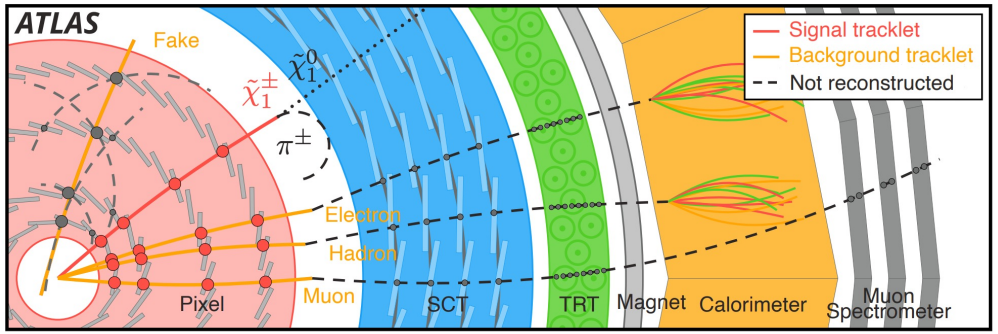
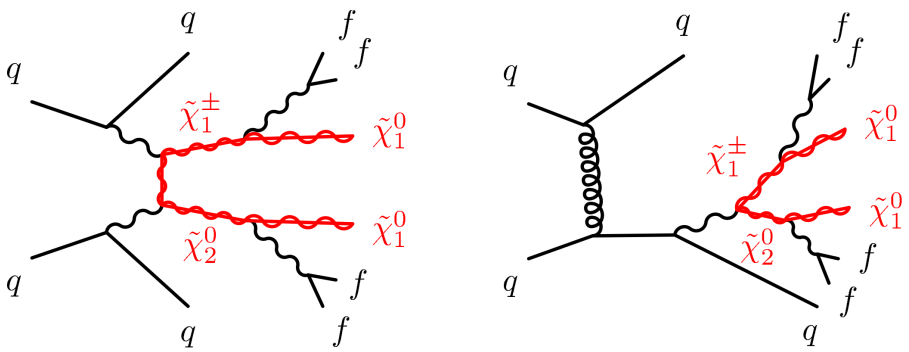
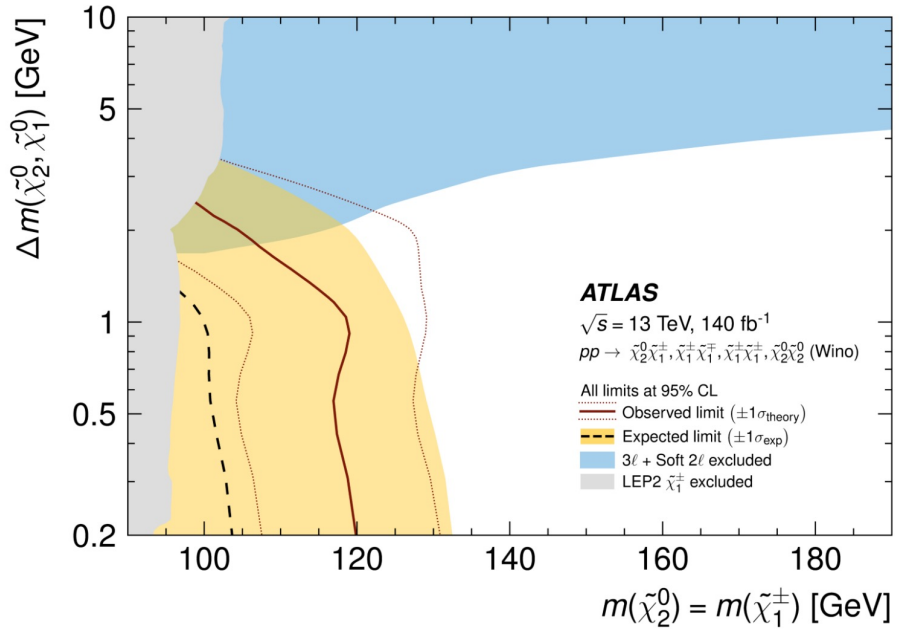


Electroweakino VBF 0L

JHEP 12 (2024) 116
(IHEP contribution)
NEW

- Pure-wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ **production** through **VBF**
- $\geq$ **2 forward jets (VBF) + large** E_T^{miss} **+ no lepton (too soft to be reconstructed)**
  - Targeting **compressed region**, favored by **Dark Matter**
- Dedicated **cross-section estimation**
  - Interference between pure-EWK and EWK/QCD diagrams
- Event selection
  - **VBF tag**: a pair of jets with largest value of m_{jj} and opposite signed pseudo-rapidity
  - A **Boosted Decision Tree** is used to discriminate between signal and background
  - **Complementary search strategies** based on jet multiplicity: '2j', '≥3j'
    - **maximize sensitivity**
    - takes into account **V+jets modeling dependence**
- No significant excess above the SM expectation
- **NSLP mass** excludes up to **117 GeV** with $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) \sim 1$ **GeV**
- **Improve sensitivity with** $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) < 2$ **GeV**



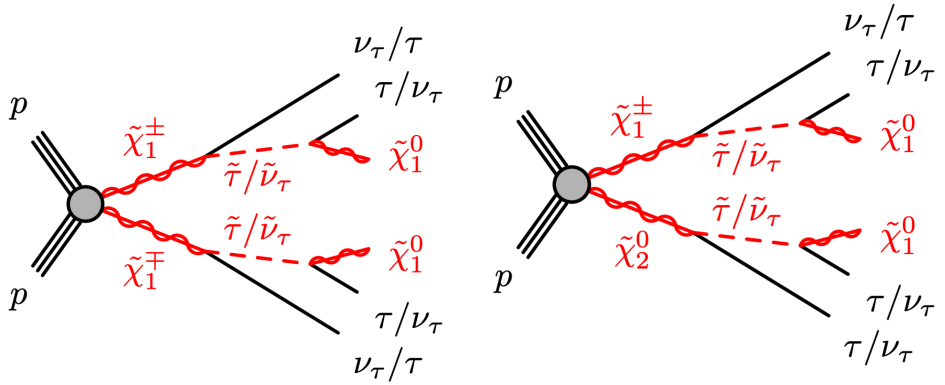


Electroweakino with intermediate-slepton

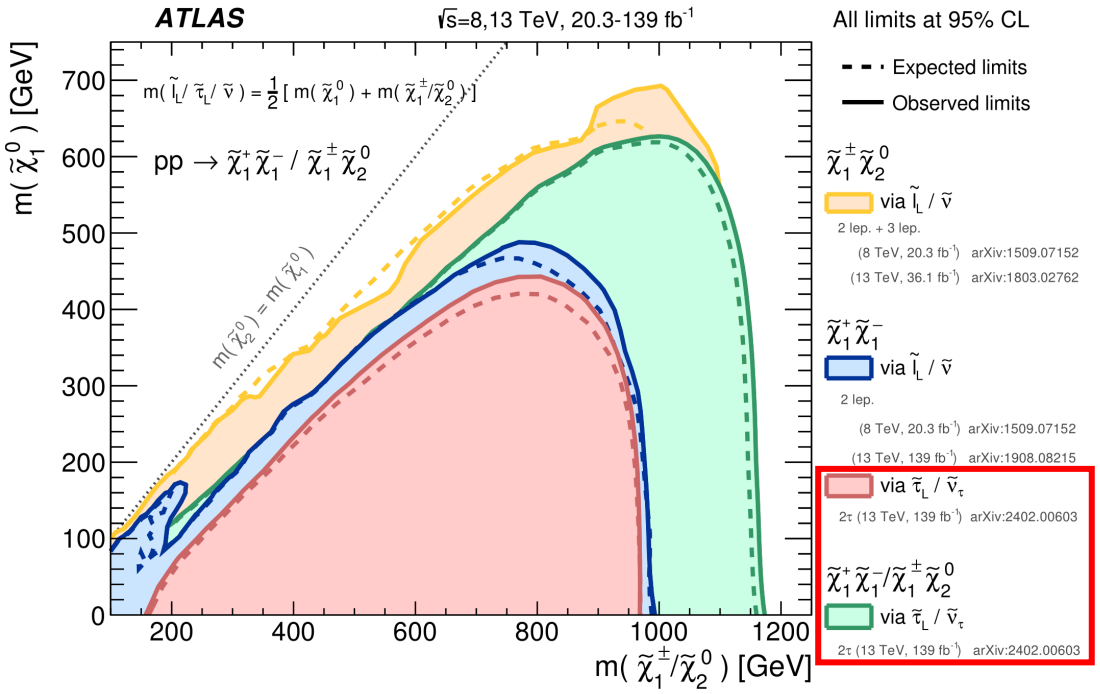
JHEP05(2024)150

IHEP contribution

- Pure-wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ **production via intermediate tau-slepton**
- $2\tau_{had}$ + large E_T^{miss}
- Analysis strategy
  - Final states: **C1C1, C1N2 (OS, SS)**
    - **First use same-sign ditau** at ATLAS, enhance sensitivity at **compressed region**
  - Parameter space: **low-mass and high-mass**
- **No significant excess** above SM expectation
- **High mass reach** improved by ~400 GeV
  - $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$ production excludes up to **970 GeV**
  - $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}/\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production excludes up to **1160 GeV**
- Sensitivity also improved at **compressed region**



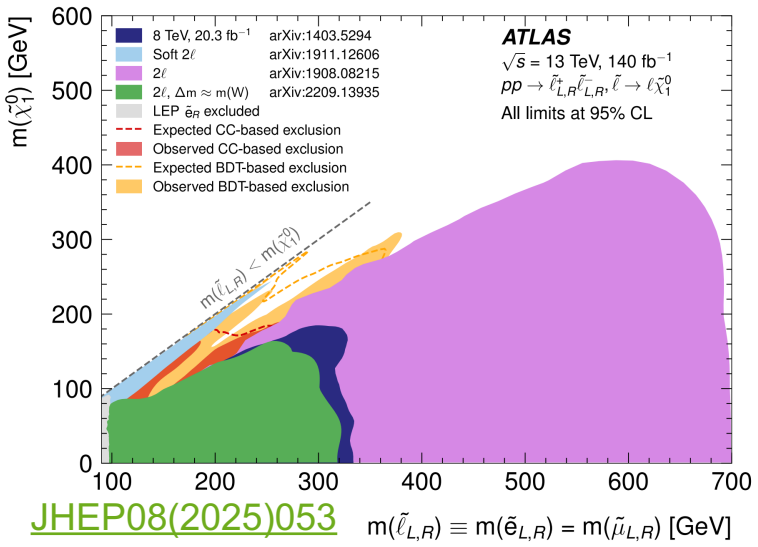
Phys. Rep. 1116 (2025) 261-300



Slepton Searches

Searches for 1st/2nd generation slepton

- Direct pair production: exclude **up to 700 GeV**
- Soft 2ℓ: exclude **< 250 GeV**
- Compressed slepton: **reduce gap in compressed region**



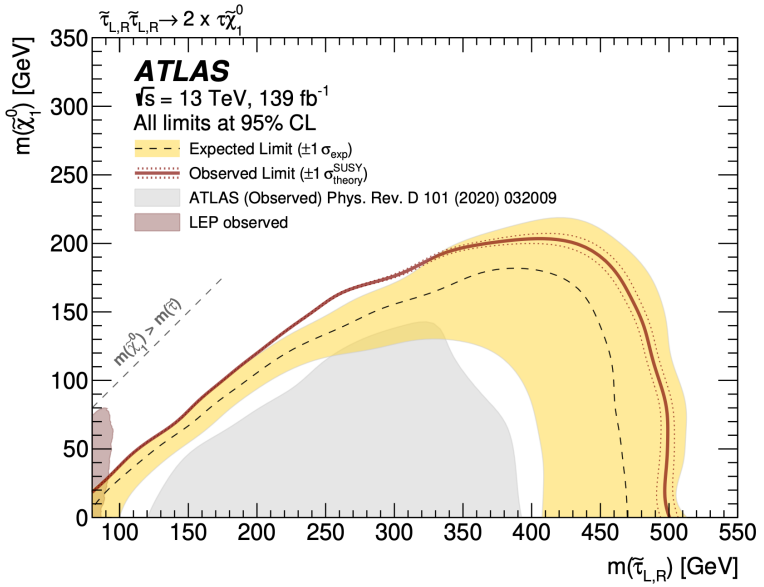
JHEP08(2025)053

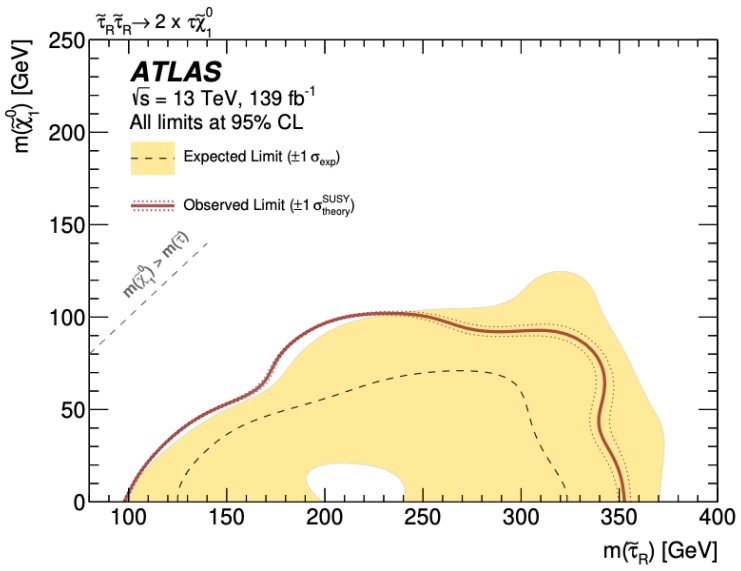
Search for **tau-slepton**

Phys. Rep. 1116 (2025) 261-300
JHEP08(2025)053
JHEP05(2024)150

- **3rd generation slepton is expected to be the lightest slepton**
- **Four BDTs targeting different $\tilde{\tau} - \tilde{\chi}_1^0$ mass regimes**
- **No significant** excess above SM expectation
- $\tilde{\tau}$ masses exclude **up to ~500 GeV**
- **Sensitivity to $\tilde{\tau}_R$-only scnario at ATLAS for the first time, exclude up to ~350 GeV**

JHEP05(2024)150
IHEP contribution





RPV reinterpretation of tau final states

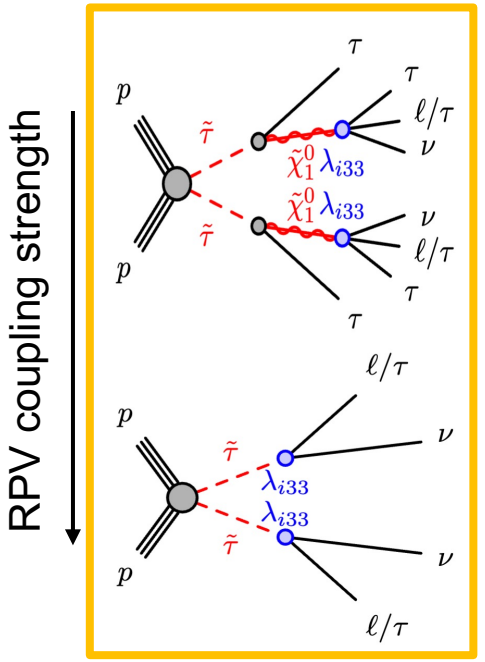
ATL-PHYS-PUB-2024-007
(IHEP contribution)

NEW

- **R-parity violation (RPV)** allows baryon and lepton number violation, and the LSP decay to SM particles.
- RPV superpotential has **coupling λ** of lepton **doublets L_i** and **singlets E_i**

$$W_{\mathrm{RPV}} = \frac{\lambda_{ijk}}{2} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{\lambda''_{ijk}}{2} \bar{U}_i \bar{D}_j \bar{D}_k + k_i L_i H_u$$

- Couplings related to **tau** are considered $\lambda_{133}, \lambda_{233}$
- **Small λ_{i33}** leads to long-lived **LSP decaying beyond the detector volume**, mimicking the MET
- **Moderate λ_{i33}** leads to **LSP decays** inside the detector with **displaced signatures**
- **Large λ_{i33}** leads to **LSP prompt decay** or **NLSP decays to SM particles**



RPV reinterpretation of tau final states

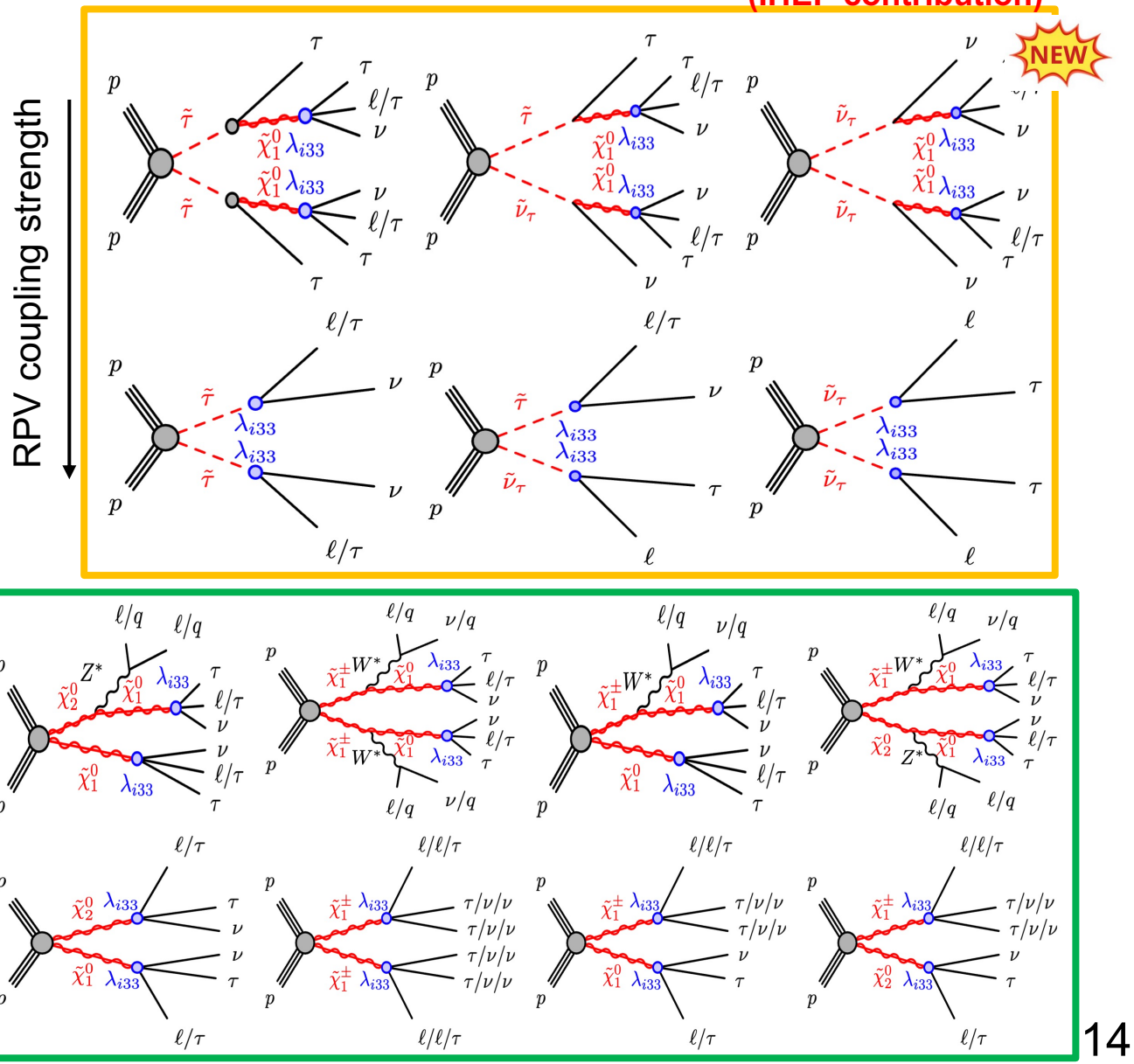
ATL-PHYS-PUB-2024-007
(IHEP contribution)

Stau model

- Production of **stau pair, stau-snu, snu pair**
- Mass degenerate left-handed and right-handed stau

Higgsino model

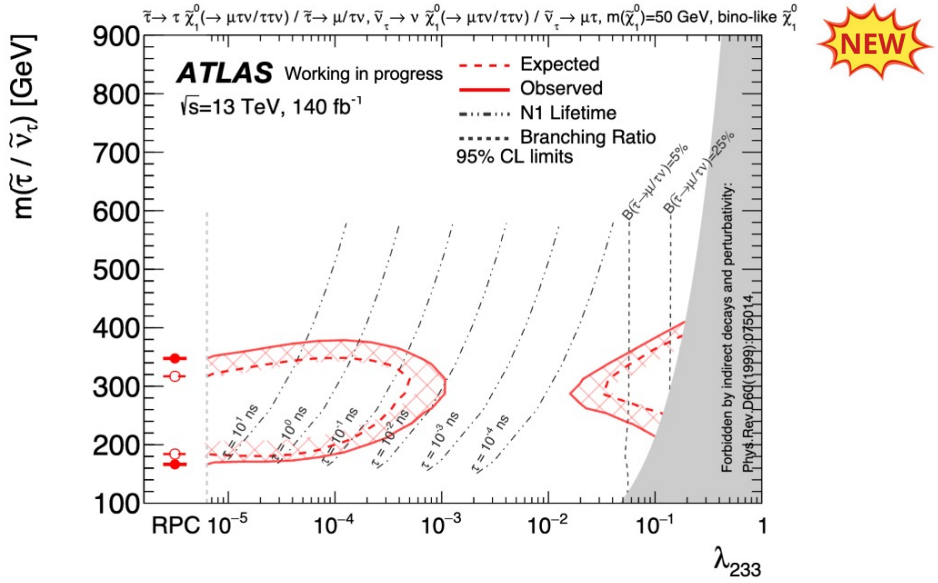
- Production of $\tilde{\chi}_1^0\tilde{\chi}_2^0$, $\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm\tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$
- Nearly mass-degenerate higgsino-like $\tilde{\chi}_1^0,\ \tilde{\chi}_2^0,\ \tilde{\chi}_1^\pm$

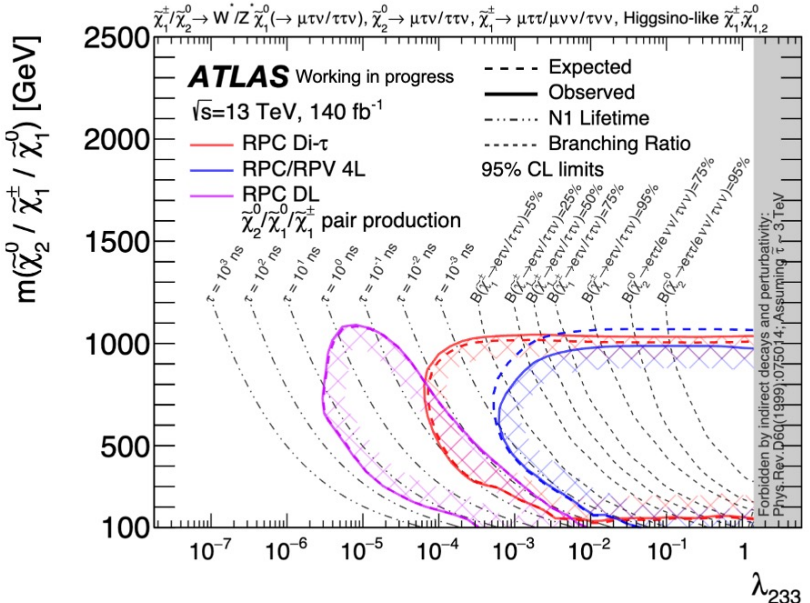


RPV reinterpretation of tau final states

ATL-PHYS-PUB-2024-007
(IHEP contribution)

- Reinterpreted searches
  - Di-tau JHEP05(2024)150
    - $\geq$ **2 hadronic tau**, large MET
  - Displaced Lepton Phys. Rev. Lett. 127, 051802
    - **Leptons** with high pT and **large impact parameter**
  - 4L JHEP07(2021)167
    - ≥ 4 **charged leptons**, large MET
- $m(\tilde{\tau}) \in [160, 340]$ GeV excluded for lifetime below 10^{-2} ns
  - Left contour for RPC-like escaping long-lived $\tilde{\chi}_1^0$
  - Right contour for di-tau final states from NLSP RPV decay
- Higgsino mass excluded up to 1100 GeV
  - Longer lifetime leads to displaced particles



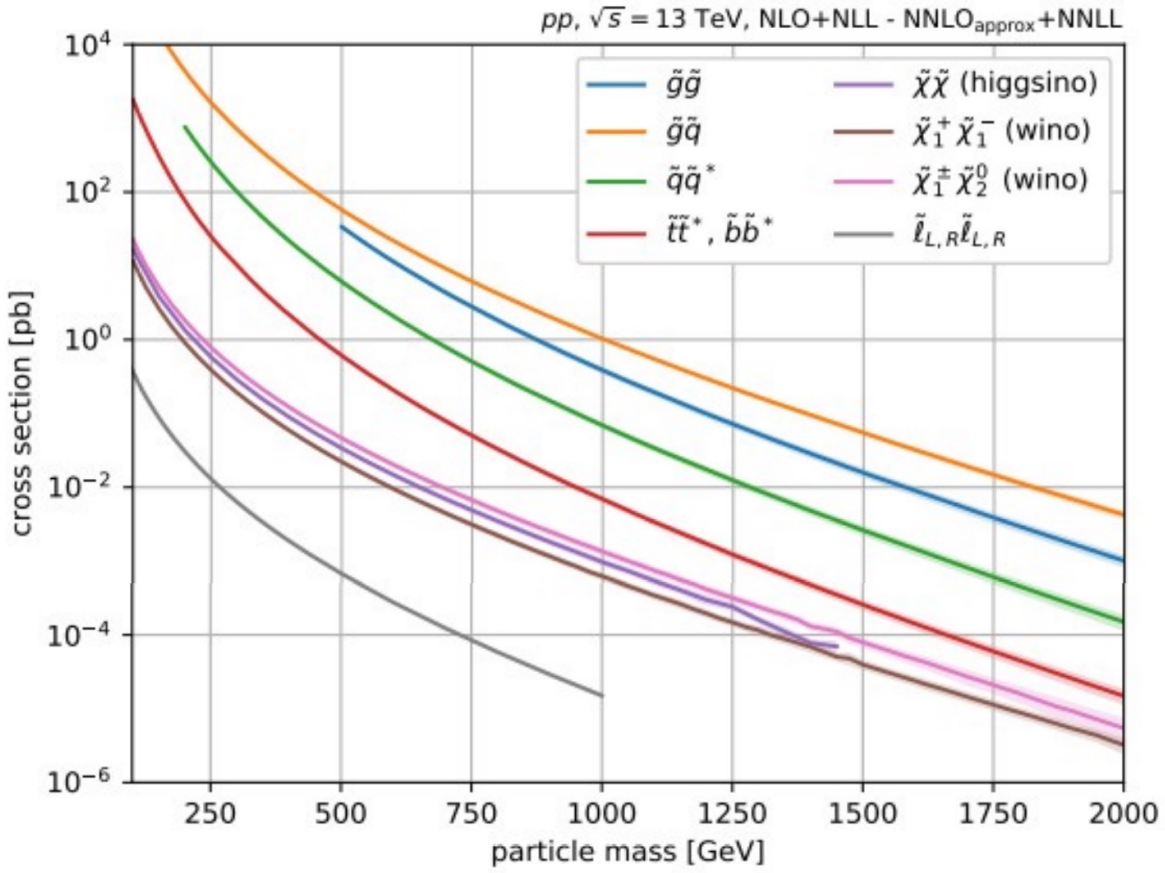


Summary

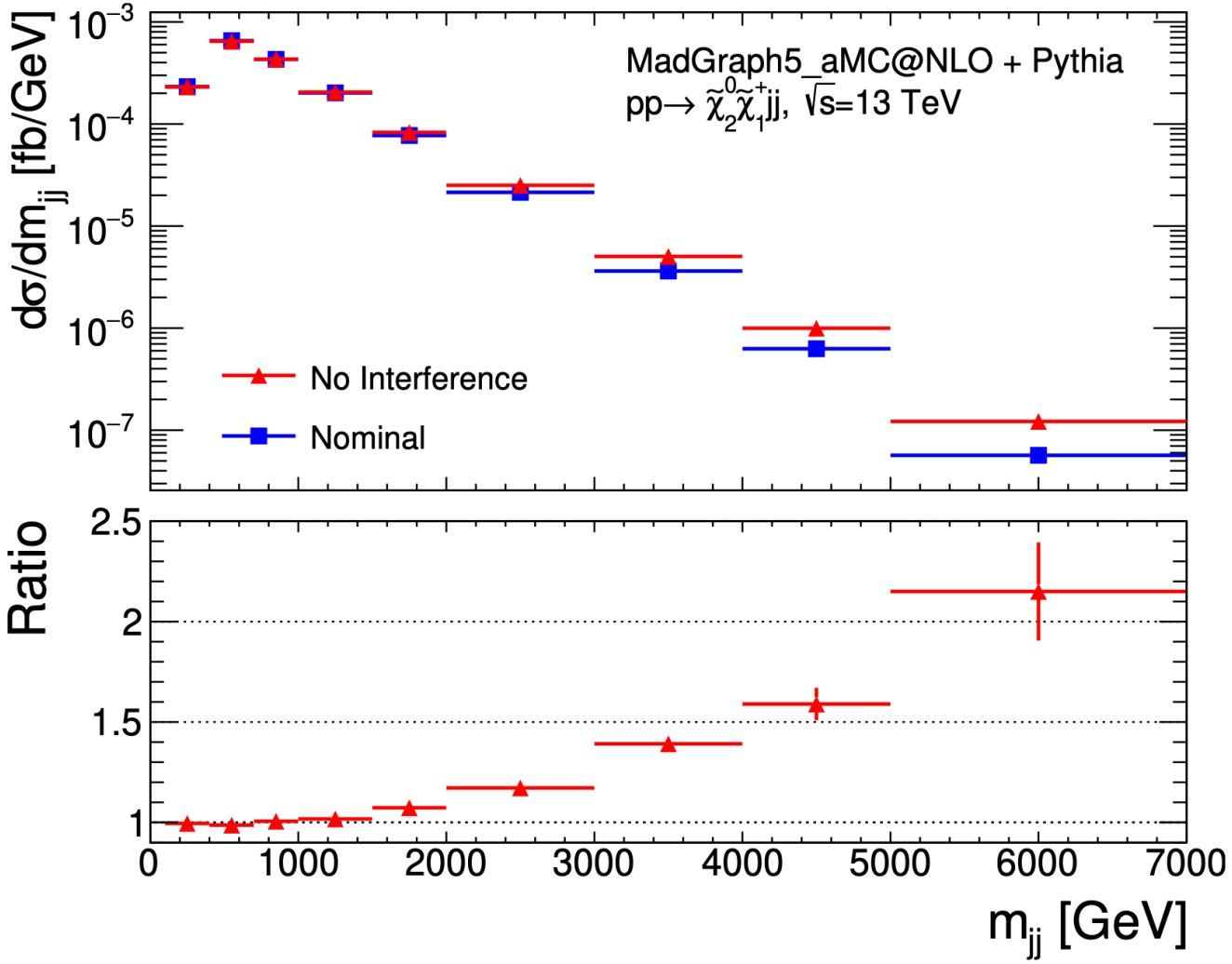
- Presented latest ATLAS results on EWK SUSY searches
  - **Challenging but well motivated scenarios** such as compressed region
  - Investigate **previously unexplored region of parameter space**
  - **ML techniques** employed to improve sensitivity
- No significant excess above SM expectation
- Covered only a small part of ATLAS results
  - ATLAS SUSY Run2 summary: Physics Reports 1116 (2025) 261–300
  - **Run3 analyses are ongoing, many interesting results are coming soon!**

- BACKUP

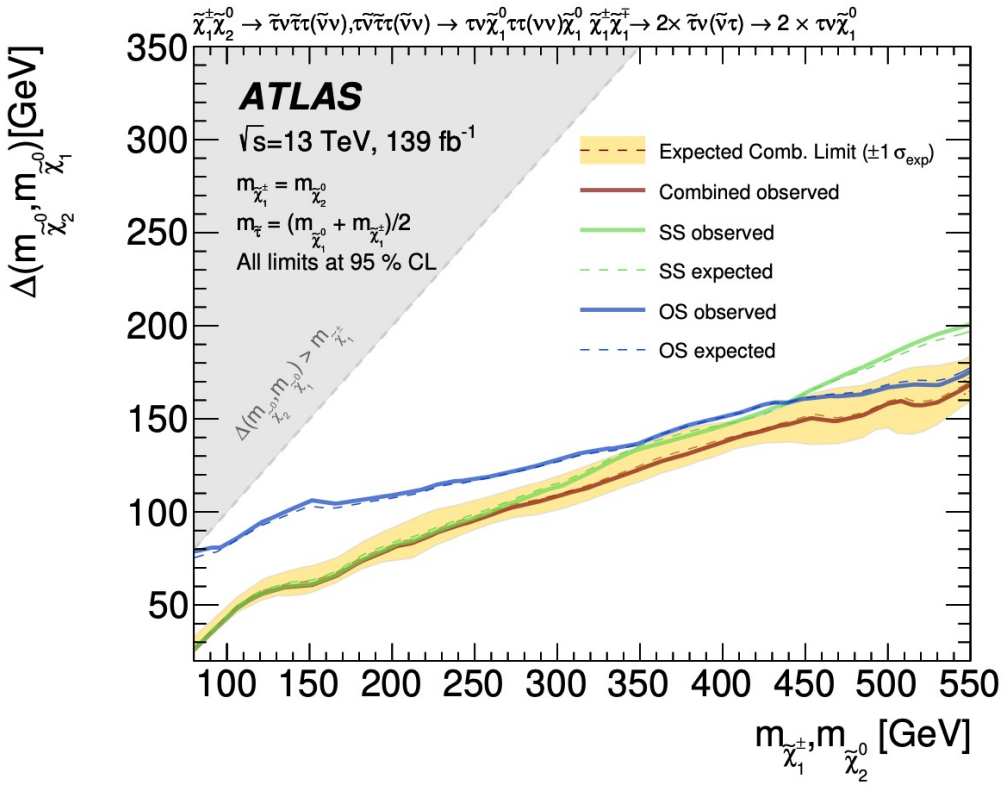
Electroweak SUSY

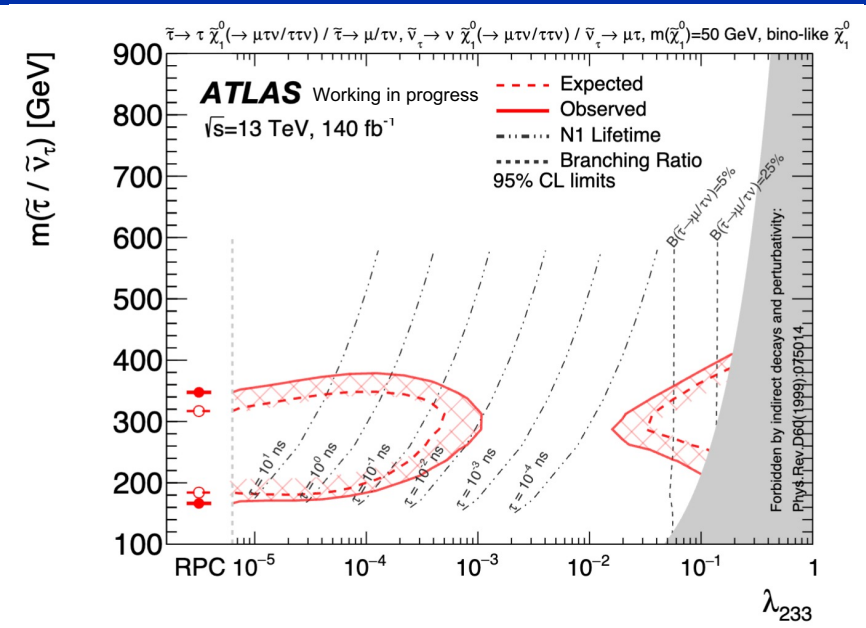


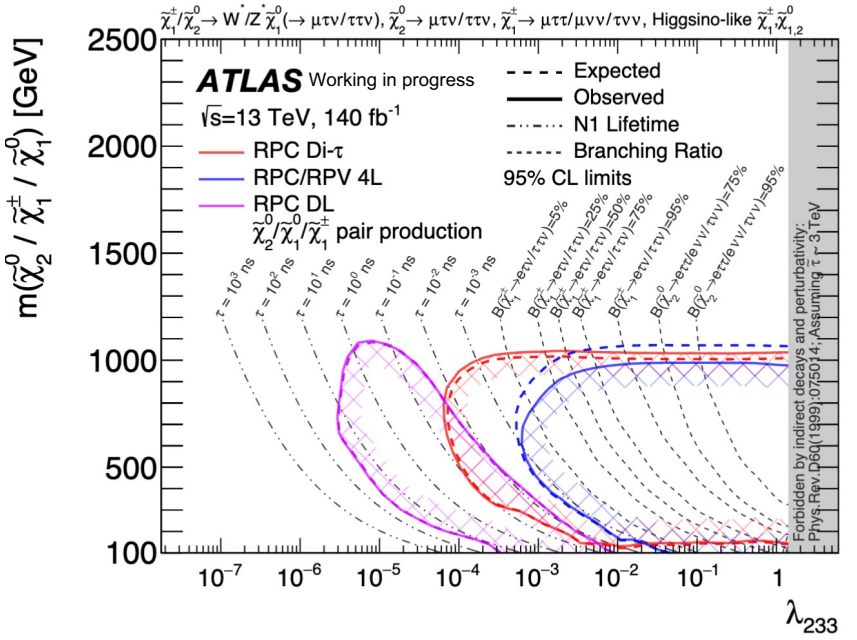
Electroweakino VBF 0L



Electroweakino with intermediate-slepton




ATLAS Working in progress
√s=13 TeV, 140 fb-1
Expected
Observed
N1 Lifetime
Branching Ratio
95% CL limits
m(τ̃ / ν̃τ) [GeV]
λ233
RPC 10−5
Forbidden by indirect decays and perturbativity: Phys.Rev.D60(1999):075014


ATLAS Working in progress
√s=13 TeV, 140 fb-1
RPC Di-τ
RPC/RPV 4L
RPC DL
Expected
Observed
N1 Lifetime
Branching Ratio
95% CL limits
m(χ̃02 / χ̃±1 / χ̃01) [GeV]
λ233
Forbidden by indirect decays and perturbativity: Phys.Rev.D60(1999):075014; Assuming τ < 3 TeV