# Searches for Electroweak SUSY


## Evelyn Thomson

**on behalf of the ATLAS Collaboration**


**PHENO 2026 in Pittsburgh**

**May 11 2026**

Penn
UNIVERSITY of PENNSYLVANIA

ATLAS EXPERIMENT

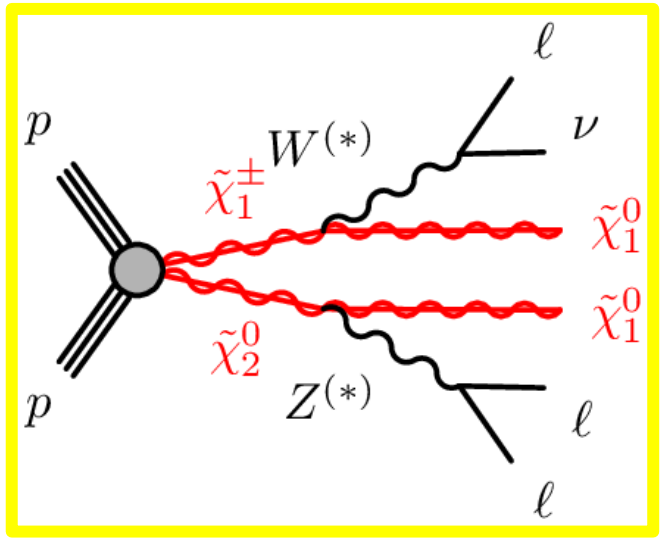
# Introduction: Electroweak Production

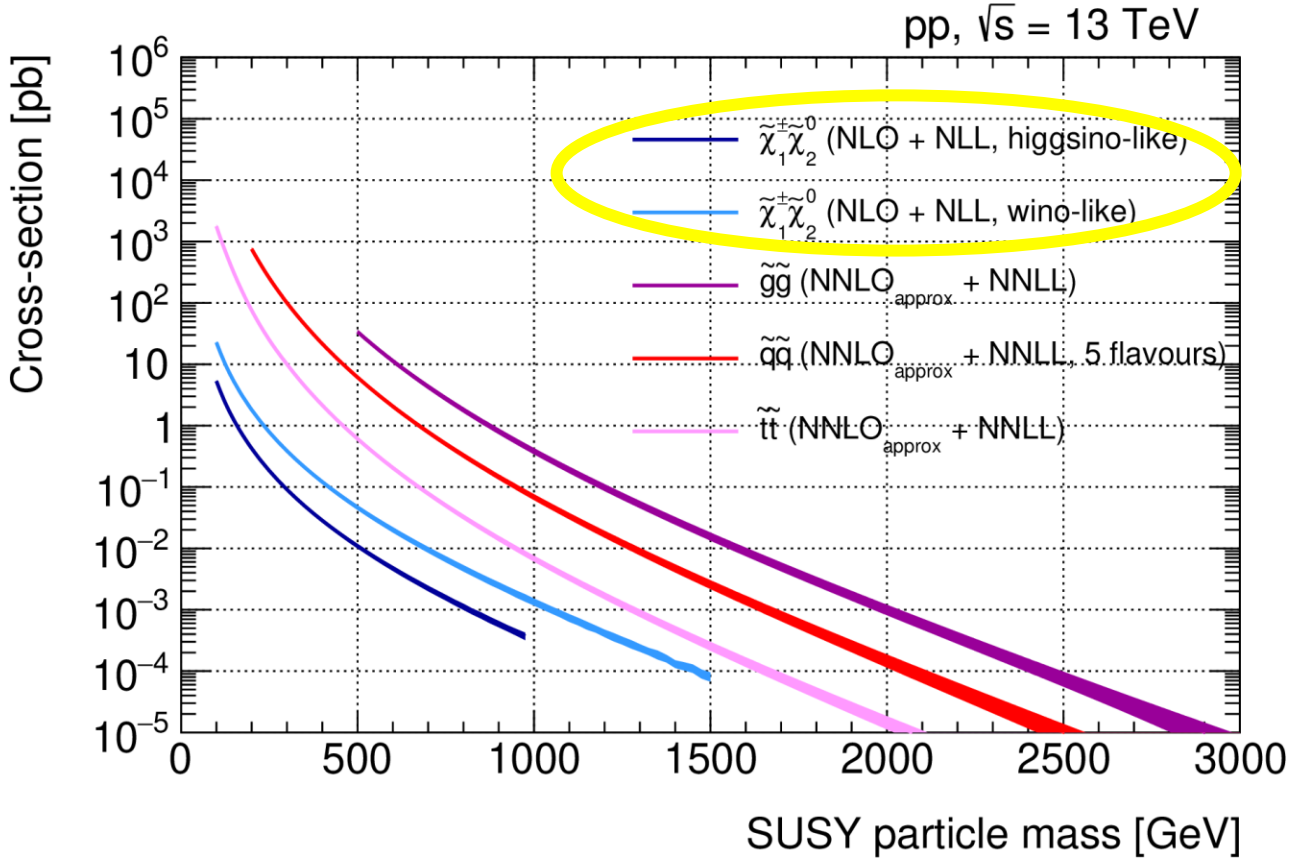
## Supersymmetric spin-1/2 partners to Electroweak and Higgs bosons

- 2 charged mass states: charginos
- 4 neutral mass states: neutralinos
- Mass states are combinations of bino, wino, higgsino states

## Rare Electroweak pair production

- C1C1, C1N2 for wino/bino
- Also C1N1, N2N1 for higgsino



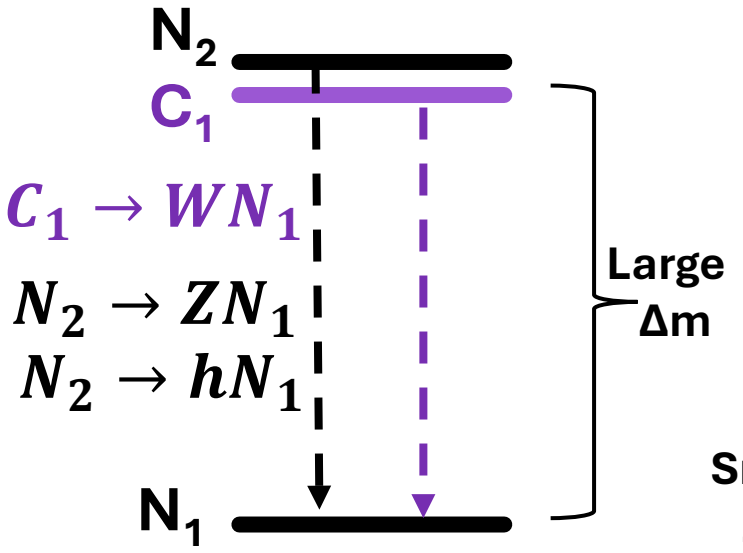

Phys. Rep. 1116 (2025) 261-300, arXiv:2403.02455

# Introduction: Electroweakino Decay

**Challenge: mass spectra and decay give huge range of experimental signatures**

- **Strategy: optimize searches for simplified models, then reinterpret**

Wino Bino
Stable N1

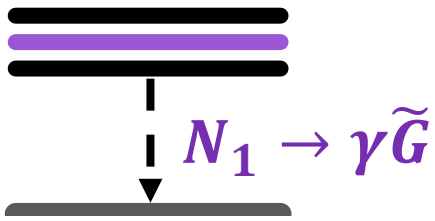



Higgsino triplet
Stable N1

arXiv:2511.20042,
submitted to JHEP

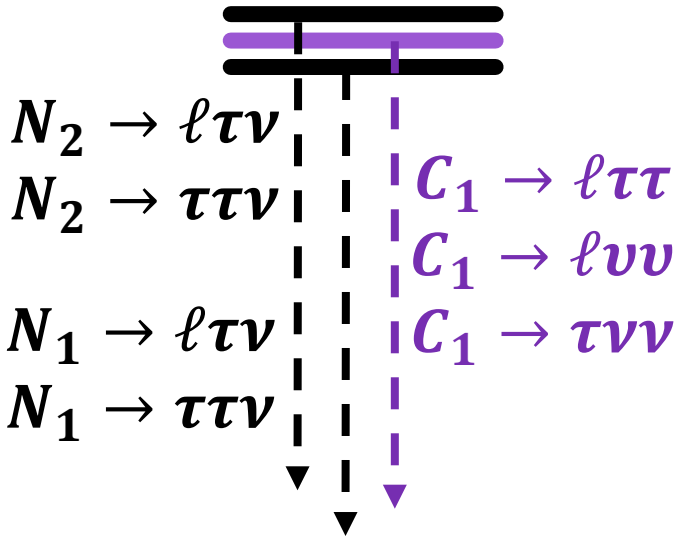

Gravity GMSB
Unstable N1

JHEP 04 (2026) 150
arXiv:2511.21240

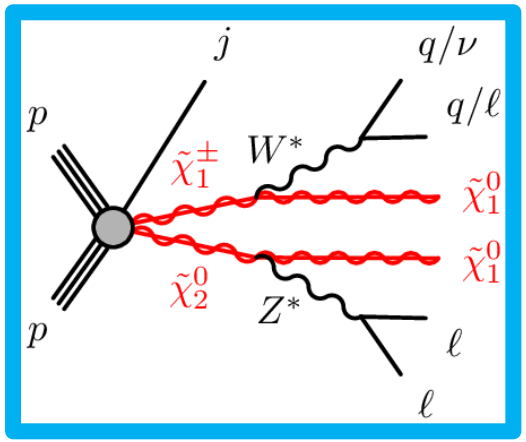



RPV
Unstable N1

arXiv:2603.15007
submitted to JHEP



# Introduction: Compressed Higgsinos




Searches explore region with small Δm (C1,N1)

Higgsino triplet
Stable N1

Pure higgsinos compressed Δm≈ 250-400 MeV

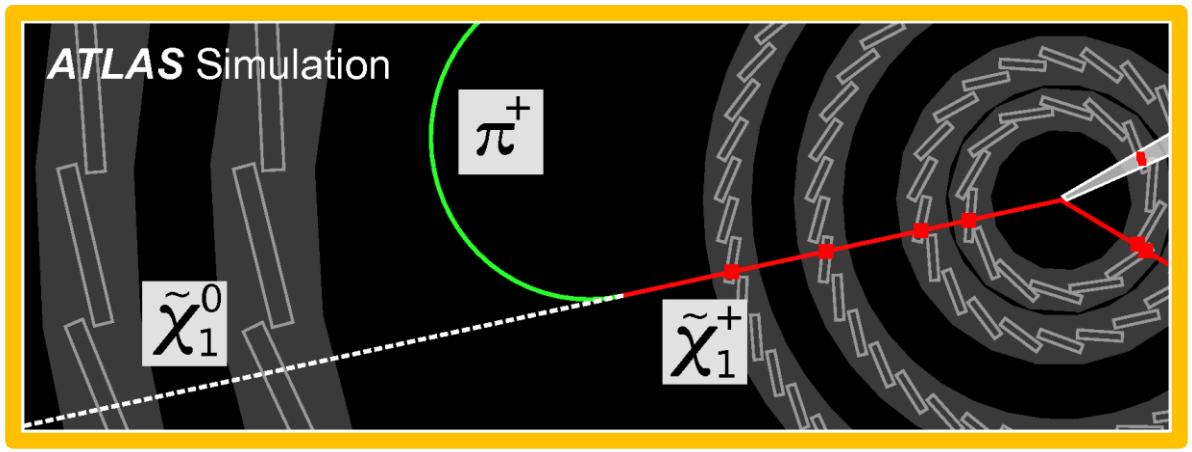
Additional Wino/Bino mixing Δm ≈ O(10 GeV)

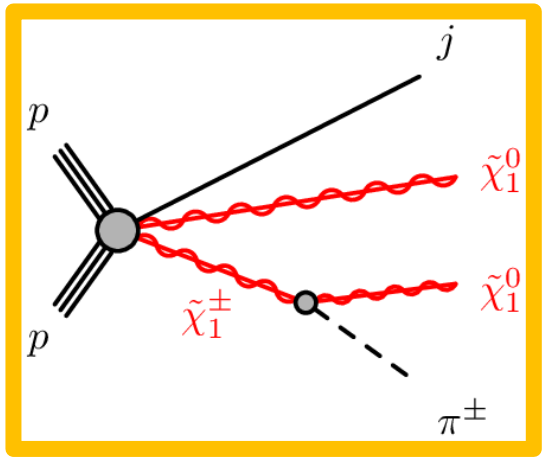
Visible decay products low $p_T$

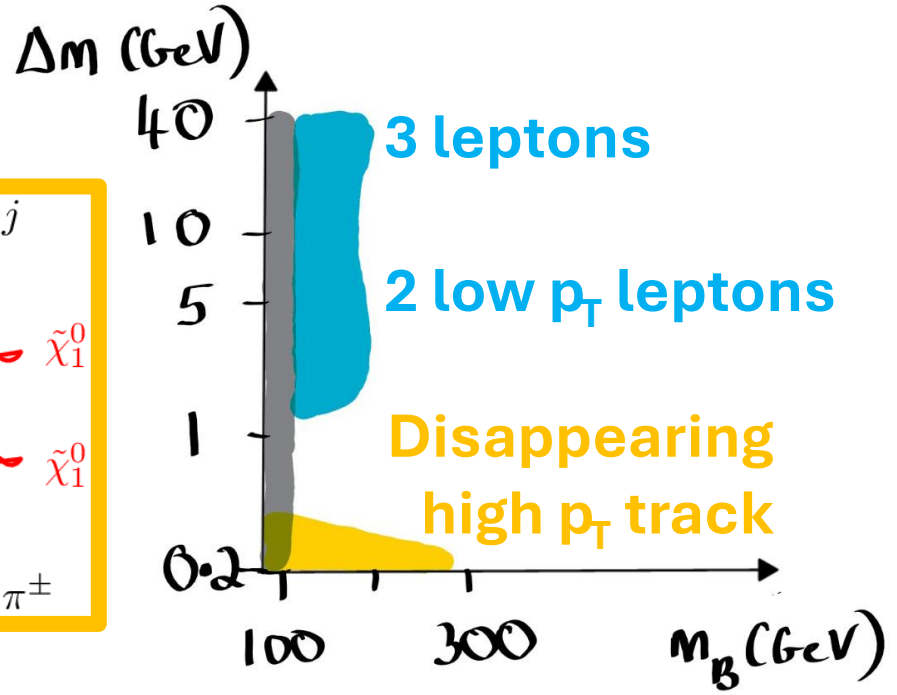
**Invisible decay products almost collinear if system recoils off Initial State Radiation jet**

- **High MET signature for triggering**

Present results in Δm vs C1 mass plane



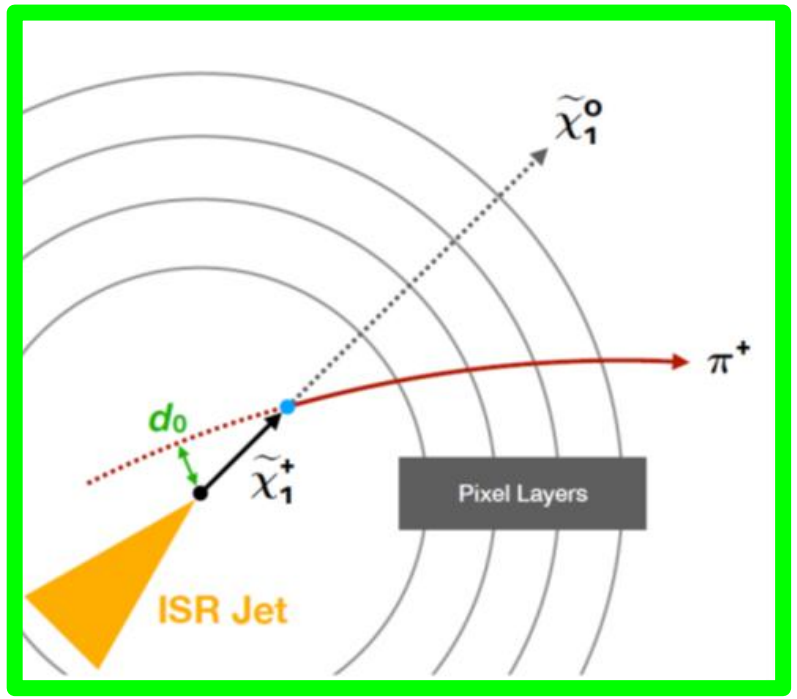




JHEP 06 (2018) 022, arXiv:1712.02118

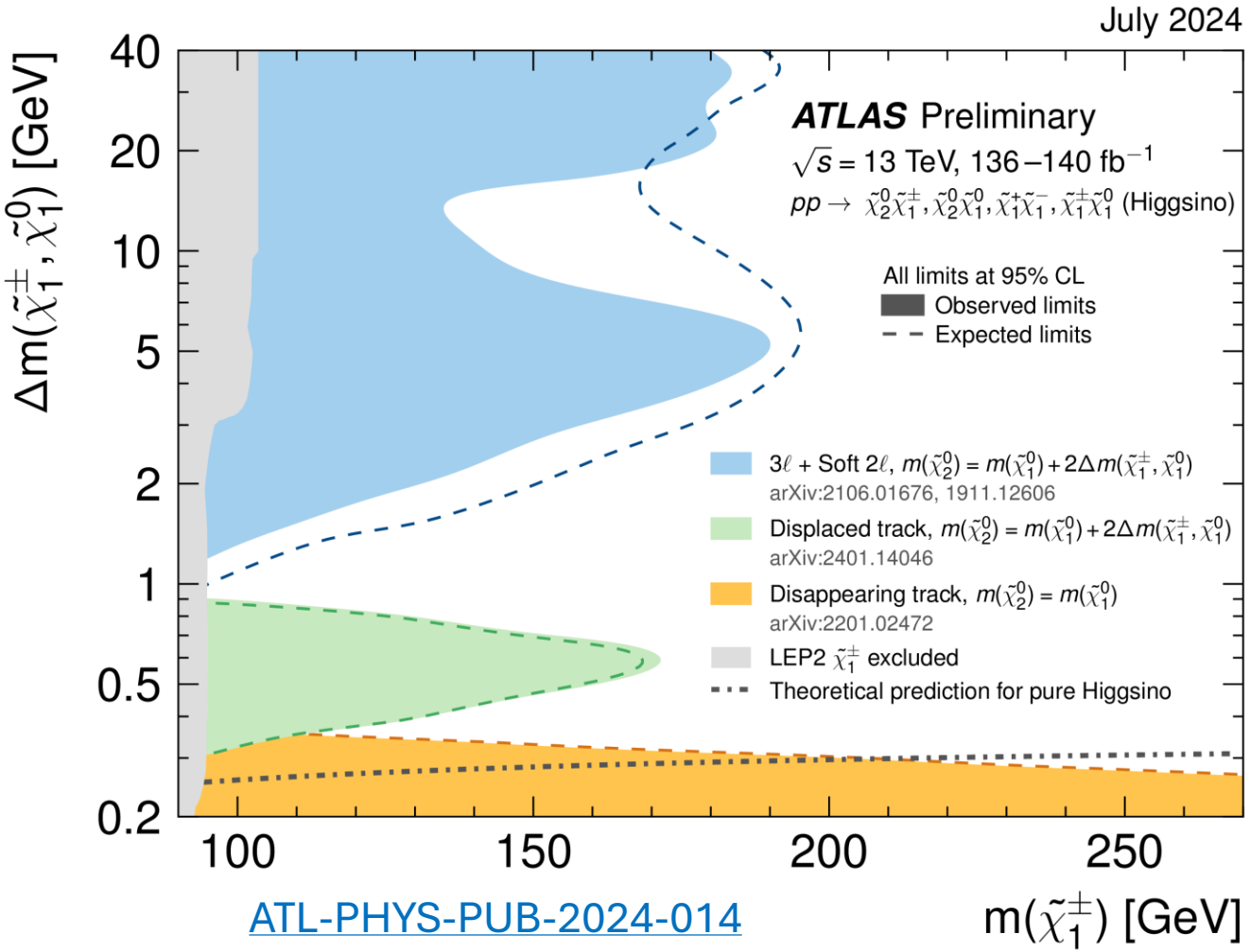
# Compressed Higgsinos in 2024

**New search** explores very interesting region with Δm of 0.3 to 1 GeV

- Displaced charged pion from decay of chargino after a few mm
  - First result in 2024
  - **First sensitivity since LEP!**




Phys. Rev. Lett. 132 (2024) 221801
arXiv:2401.14046




ATL-PHYS-PUB-2024-014

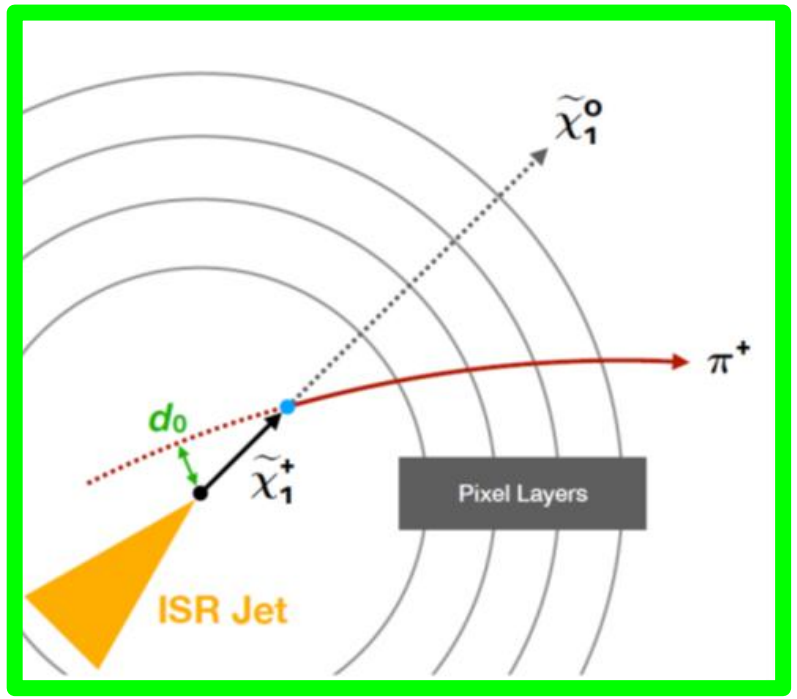
# Compressed Higgsinos in 2024

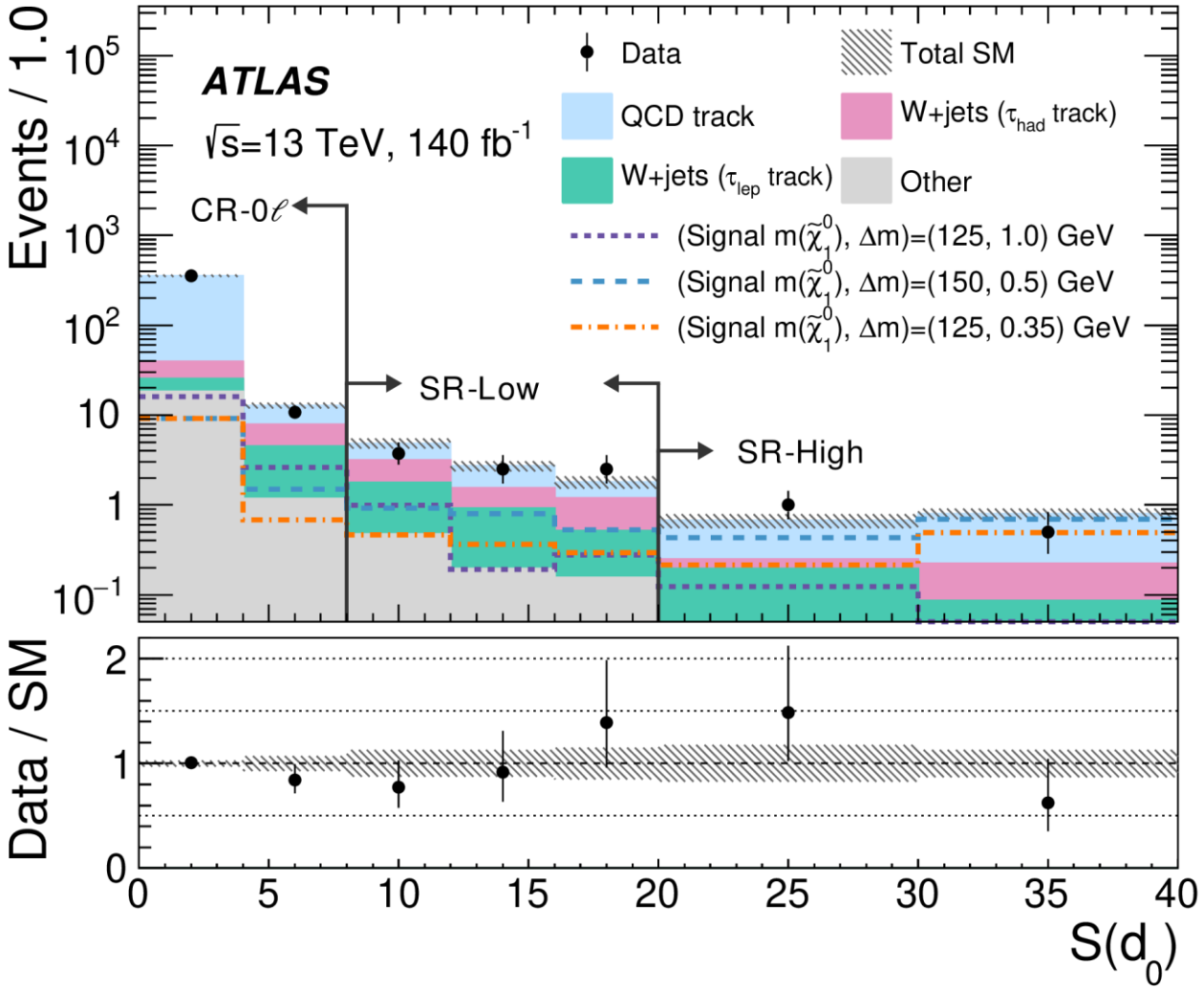
## First displaced charged pion search

Impact parameter ($d_0$) significance for 2 orthogonal signal regions

No significant deviation observed from post-fit background

Phys. Rev. Lett. 132 (2024) 221801
arXiv:2401.14046

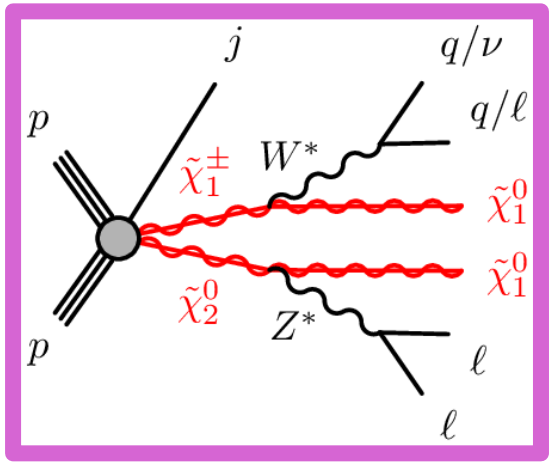


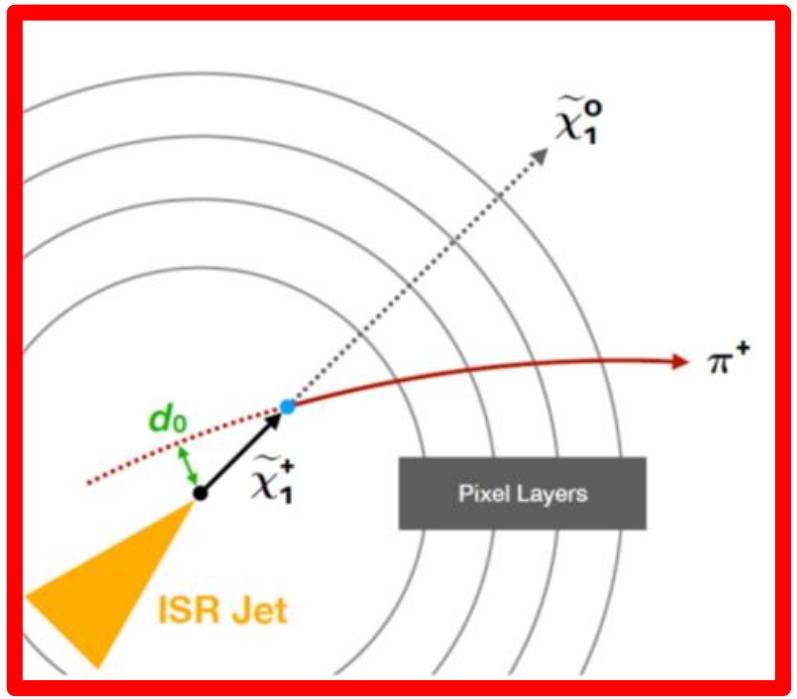



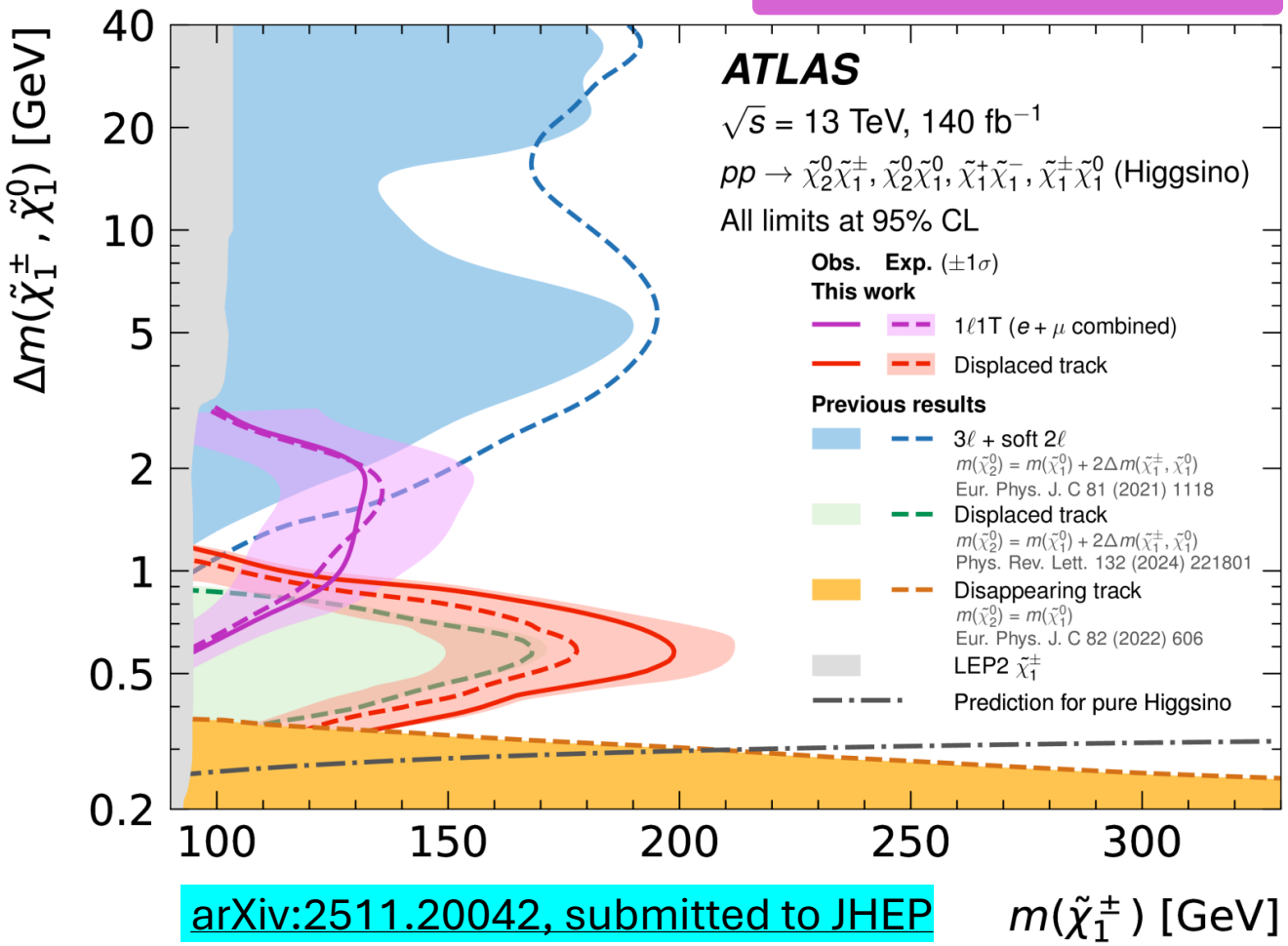
# Compressed Higgsinos in 2026

**Two new searches explore very interesting region with Δm of 0.3 to 2 GeV**

- New result with 1 lepton+1 track
- New displaced charged pion search with NNs extends reach



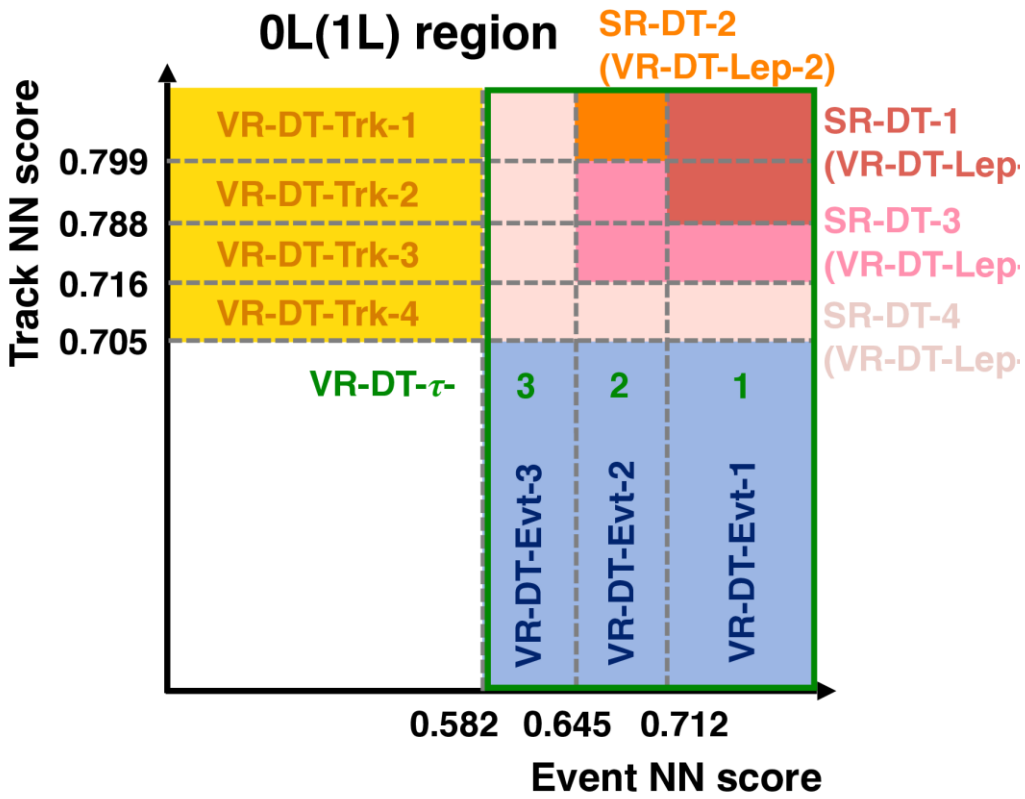

arXiv:2511.20042, submitted to JHEP

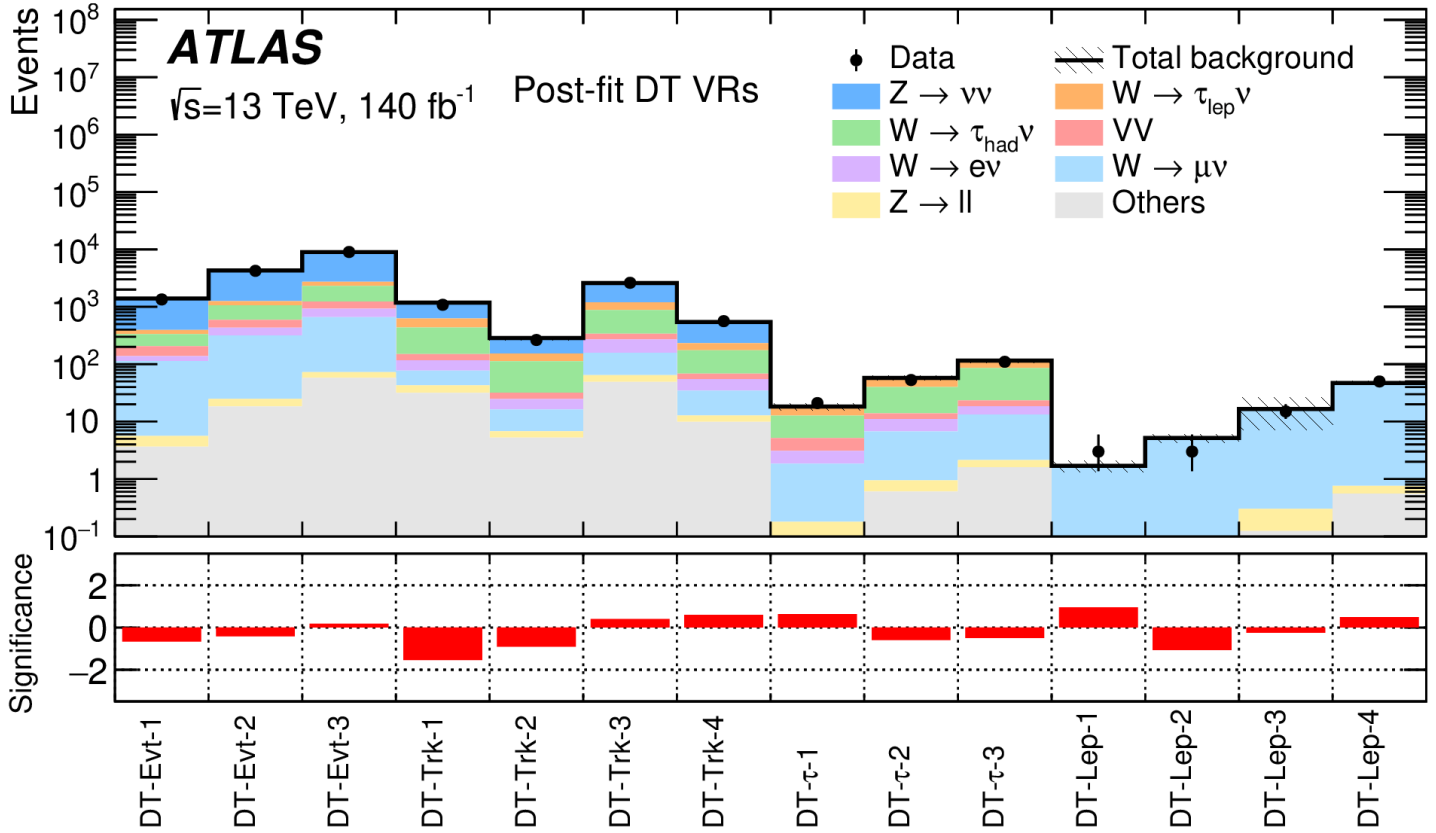
# Compressed Higgsinos with Neural Nets

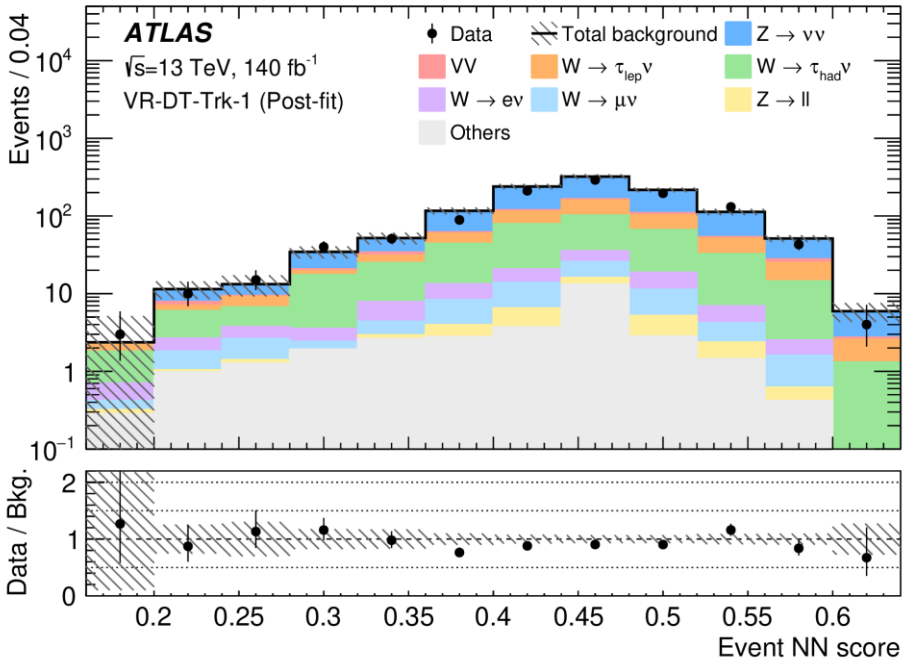
## Displaced charged pion with NNs

arXiv:2511.20042, submitted to JHEP

- Event-level NN (MET, jet $p_T$)
- Track-level NN (d0 significance, track $p_T$, isolation)
- SRs and VRs defined within 2D plane of NN scores



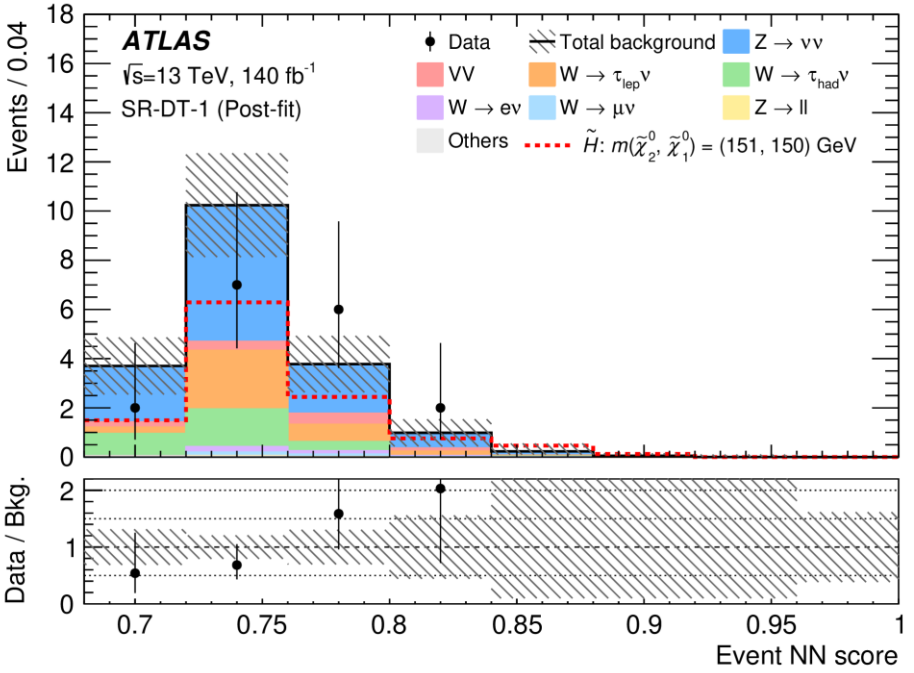



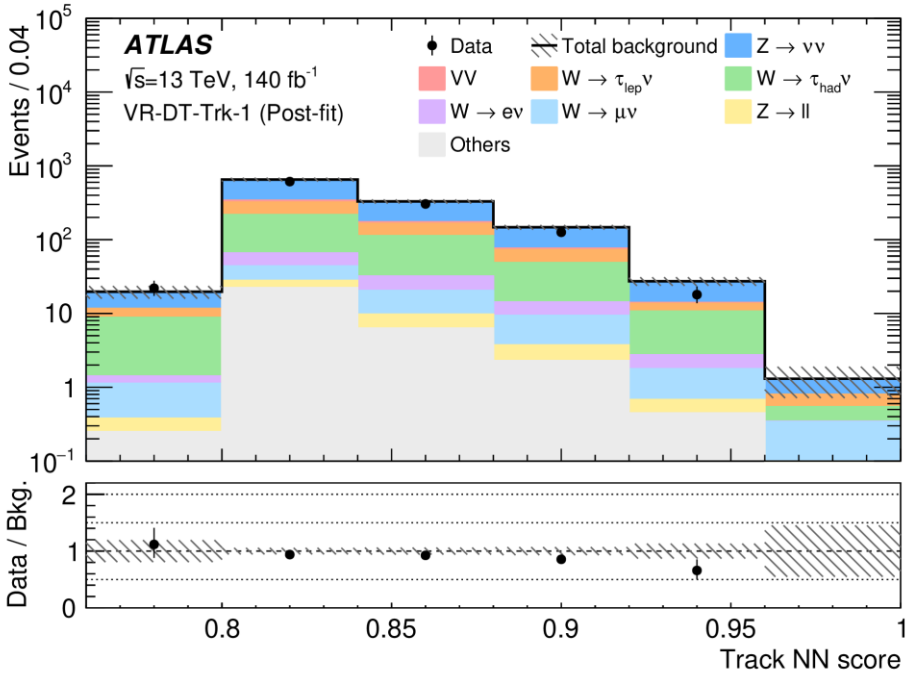


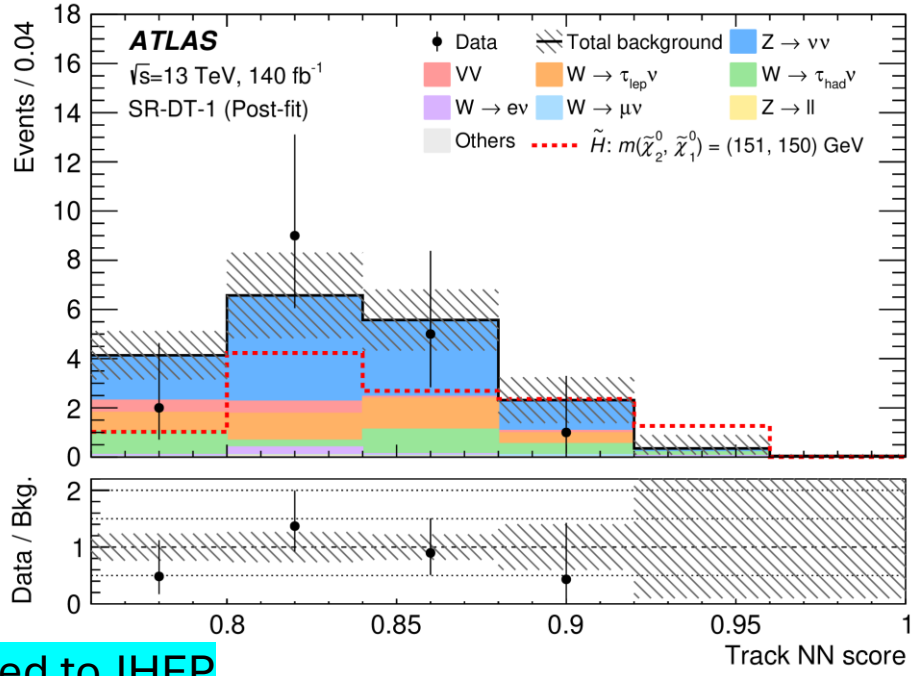

## Event NN

## Validation Regions → Signal Region DT-1

## Track NN



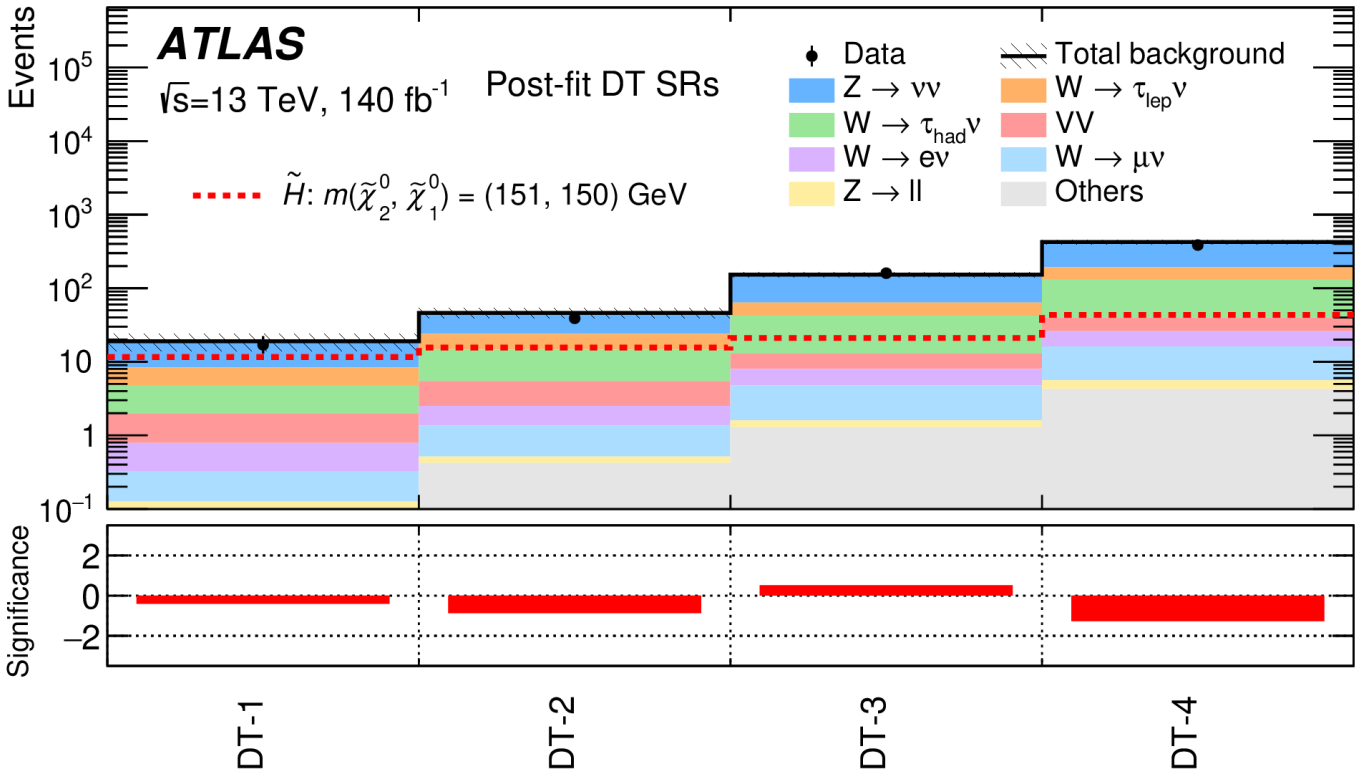



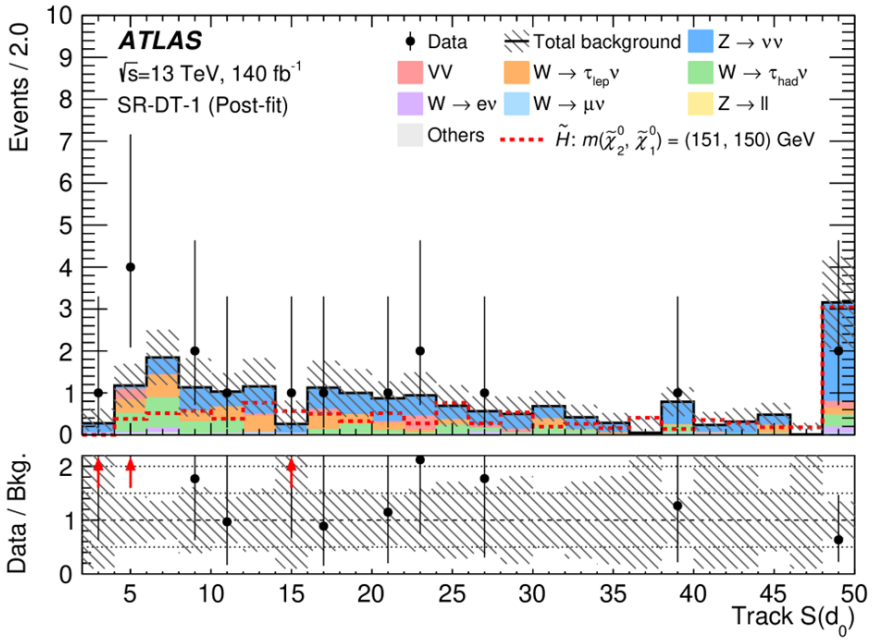

arXiv:2511.20042, submitted to JHEP

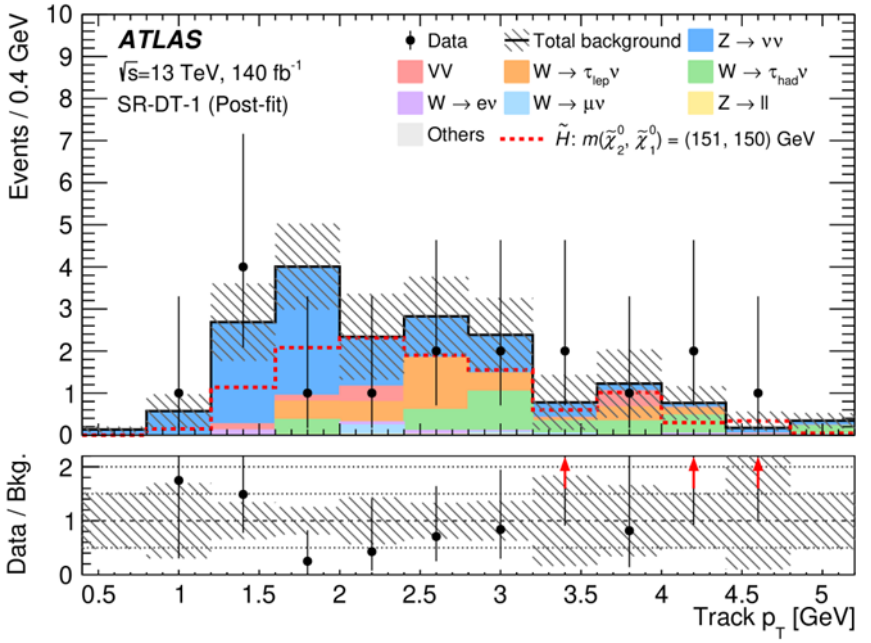
# Compressed Higgsinos

## Displaced charged pion with NNs

### 4 signal regions. No significant deviation observed from post-fit background



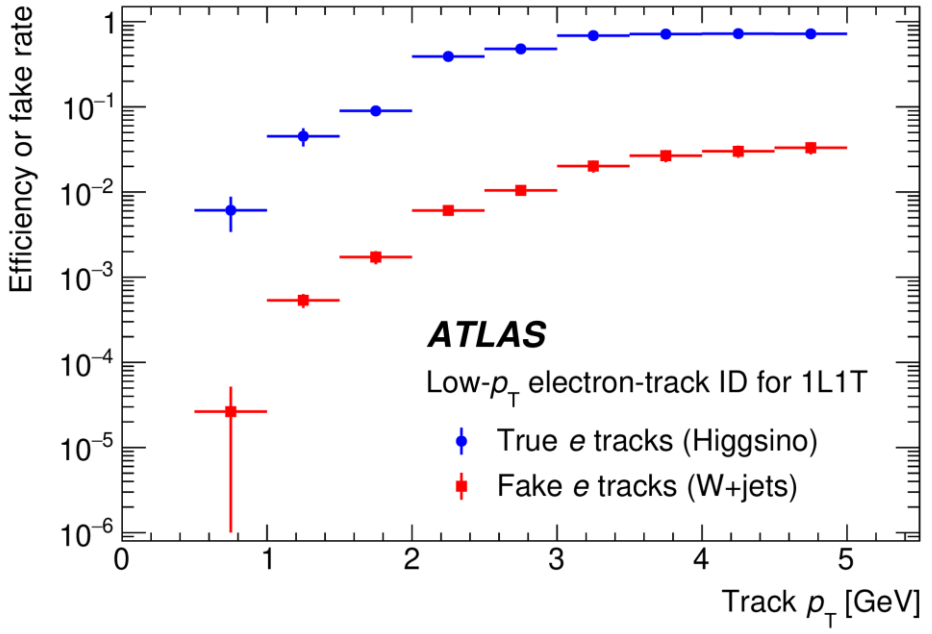

arXiv:2511.20042, submitted to JHEP

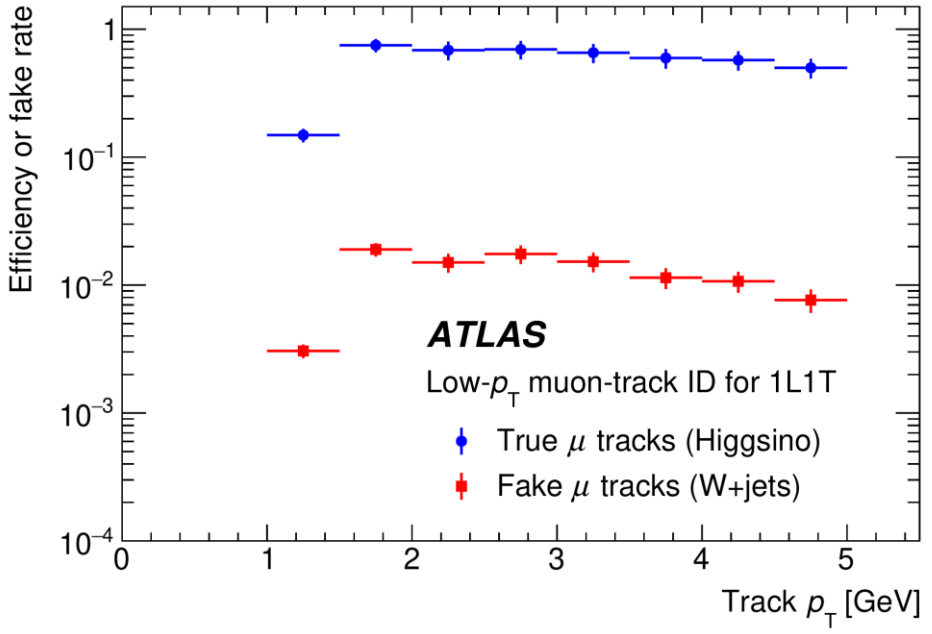
# Compressed Higgsinos

## 1 lepton + 1 track

Developed new "lepton-track" ID with DNNs to identify very low $p_T$ leptons

- Calibrated via $Z \to ee\gamma$ thanks to asymmetric final state with FSR photon
  - High $p_T$ electron or positron
  - Low $p_T$ positron or electron tends to be collinear with FSR photon
- Calibrated with $J/\psi \to \mu\mu$




arXiv:2511.20042, submitted to JHEP

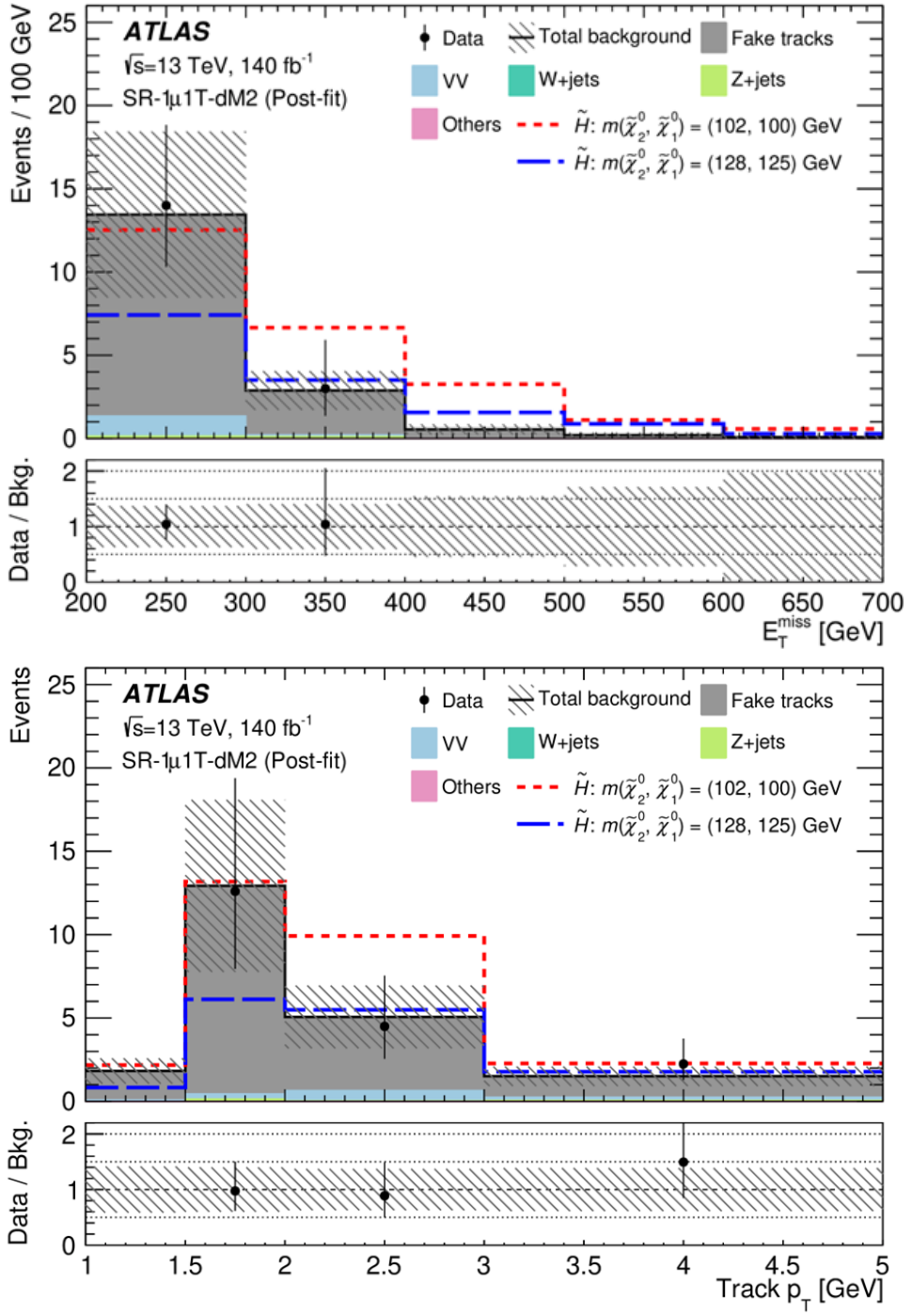
# Compressed Higgsinos

## 1 lepton + 1 track

Developed "pNN" parameterized by Δm and 16 inputs

- Data-driven background estimate using control regions
- Six non-orthogonal SRs per lepton flavor (electron or muon)

Signal region kinematics shown for 1 muon + 1 track with pNN Δm = 2 GeV

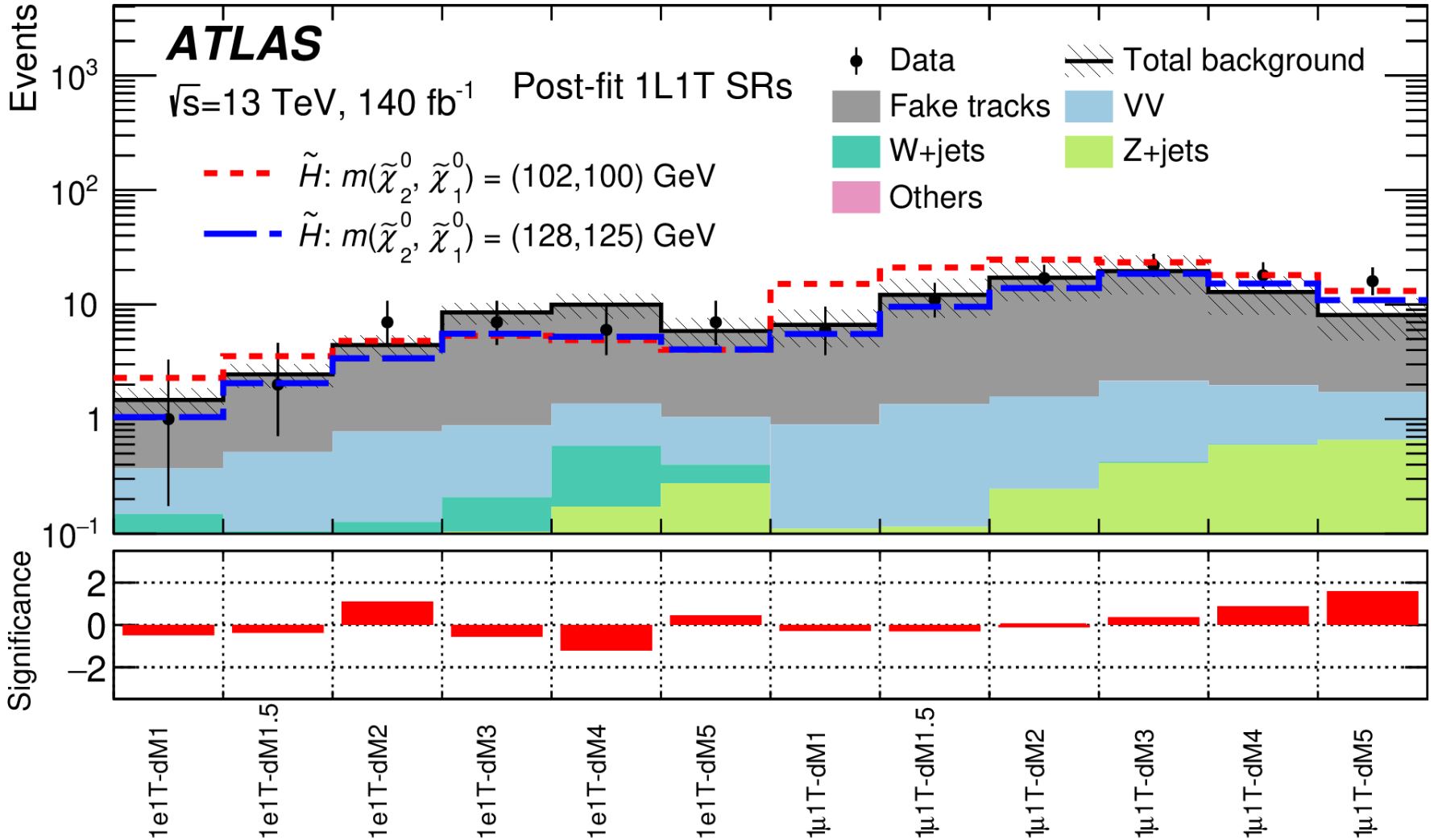



arXiv:2511.20042, submitted to JHEP

# Compressed Higgsinos

arXiv:2511.20042, submitted to JHEP

**1 lepton + 1 track: no significant deviation observed from post-fit background in six non-orthogonal signal regions per lepton flavor**



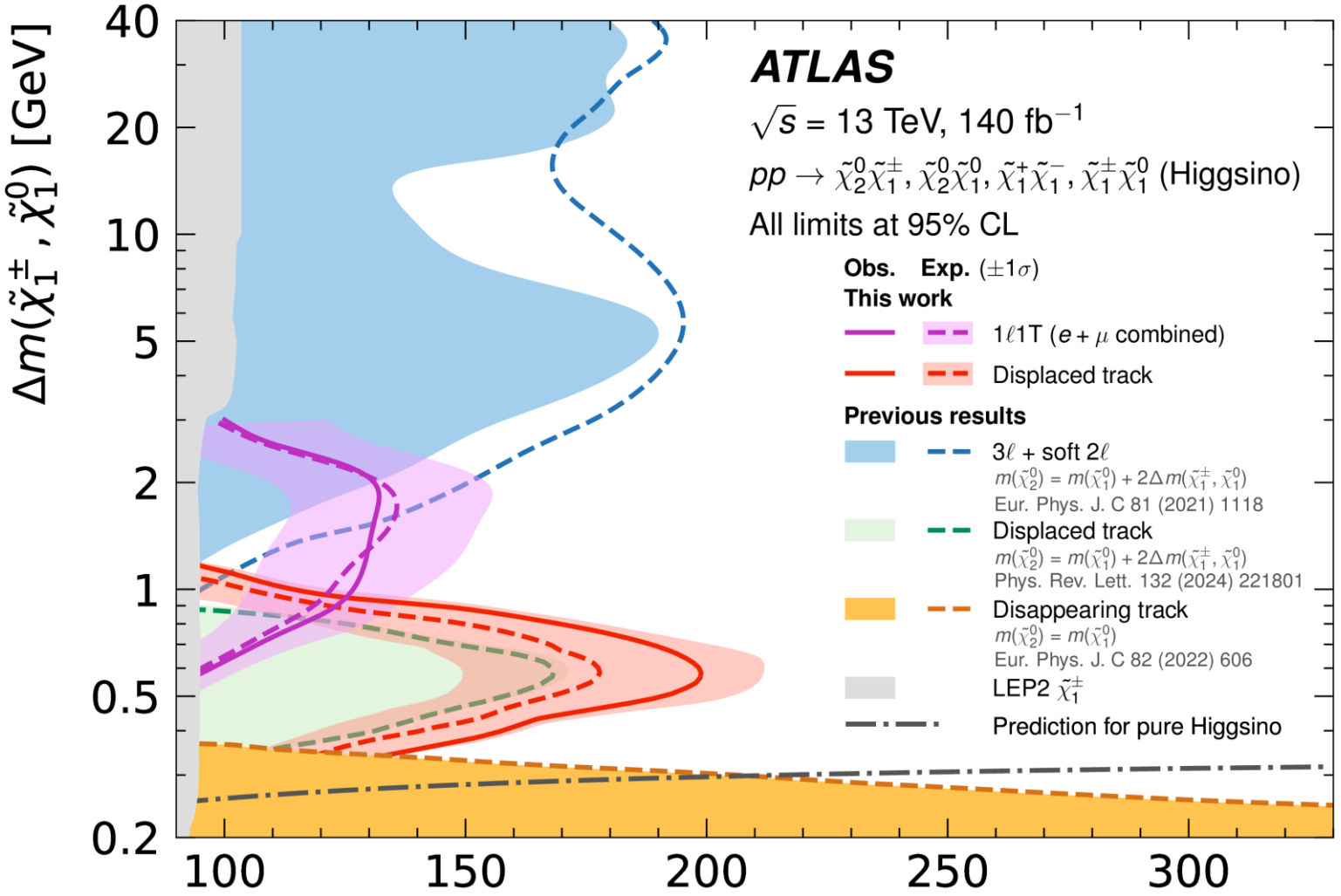
# Compressed Higgsinos in 2026

New searches with Run 2 data have extended limits over entire compressed Δm region for first time since LEP!

- 1 lepton+1 track
- Displaced charged pion

Chargino mass > 126 GeV at 95% CL

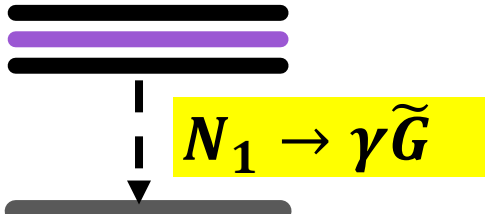
Looking forward to Run 3 results with 2x data!




arXiv:2511.20042, submitted to JHEP

# Higgsinos to γ/Z/h and gravitino

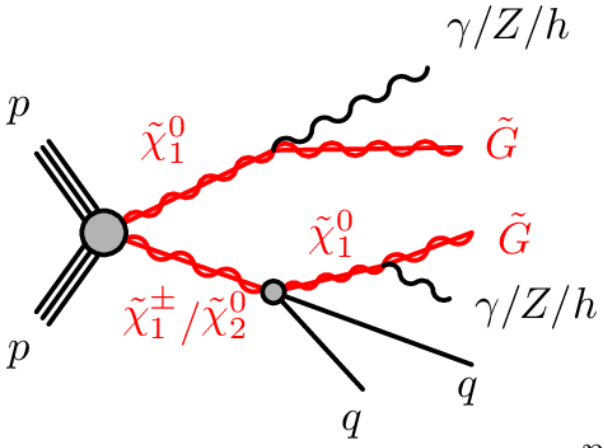
Gravity GMSB
Unstable N1

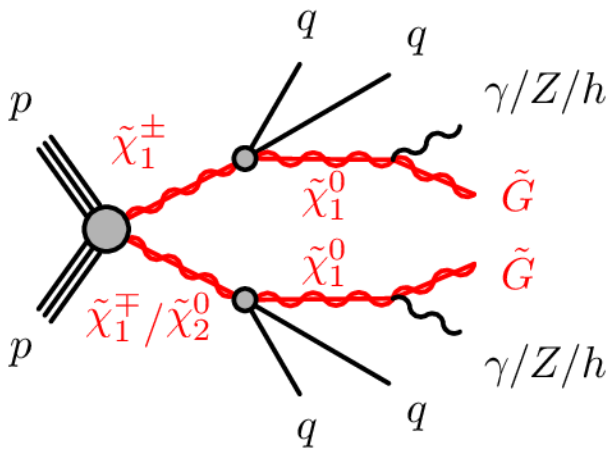


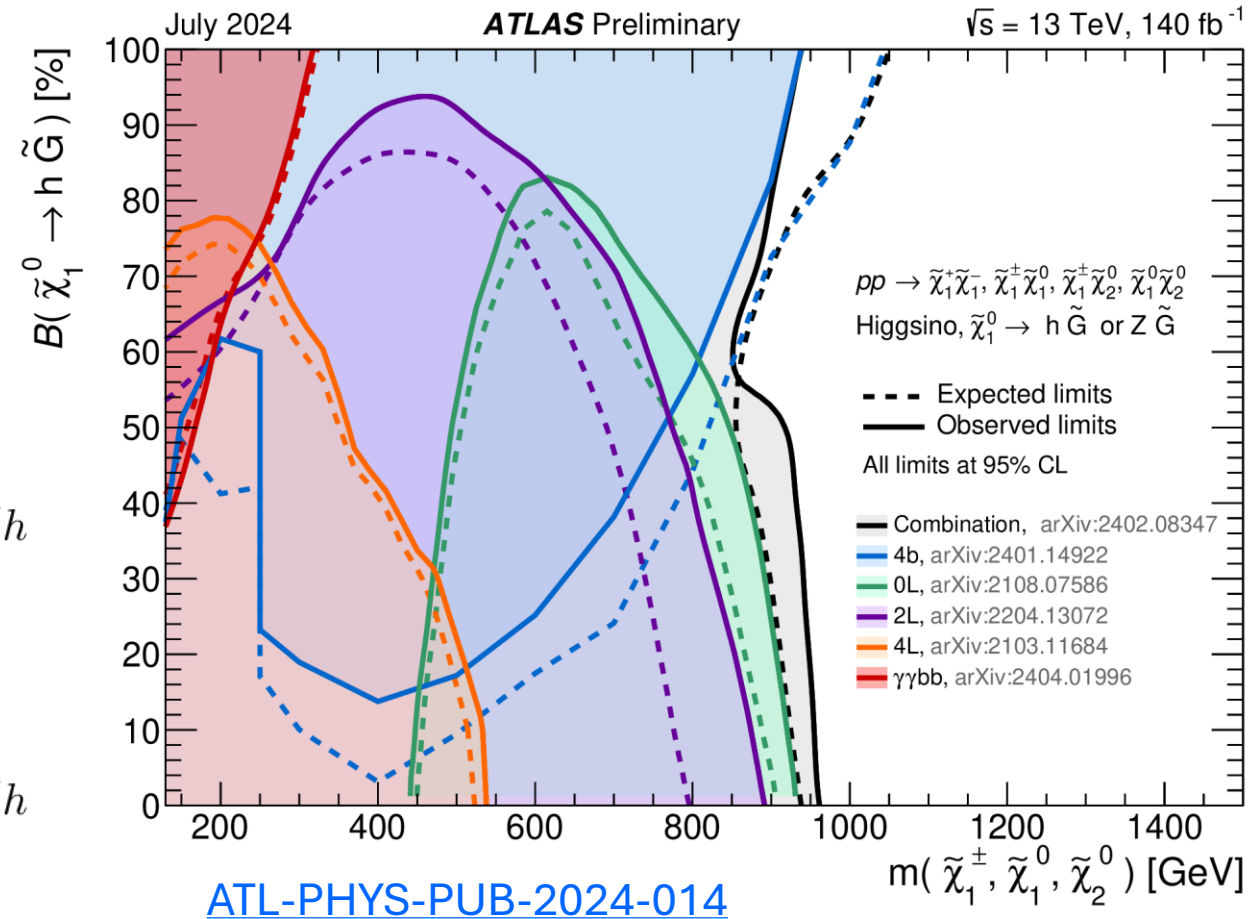

## Summary plot from July 2024

- Higgsino decays to gravitinos with Higgs or Z bosons

## New result for decays with photons



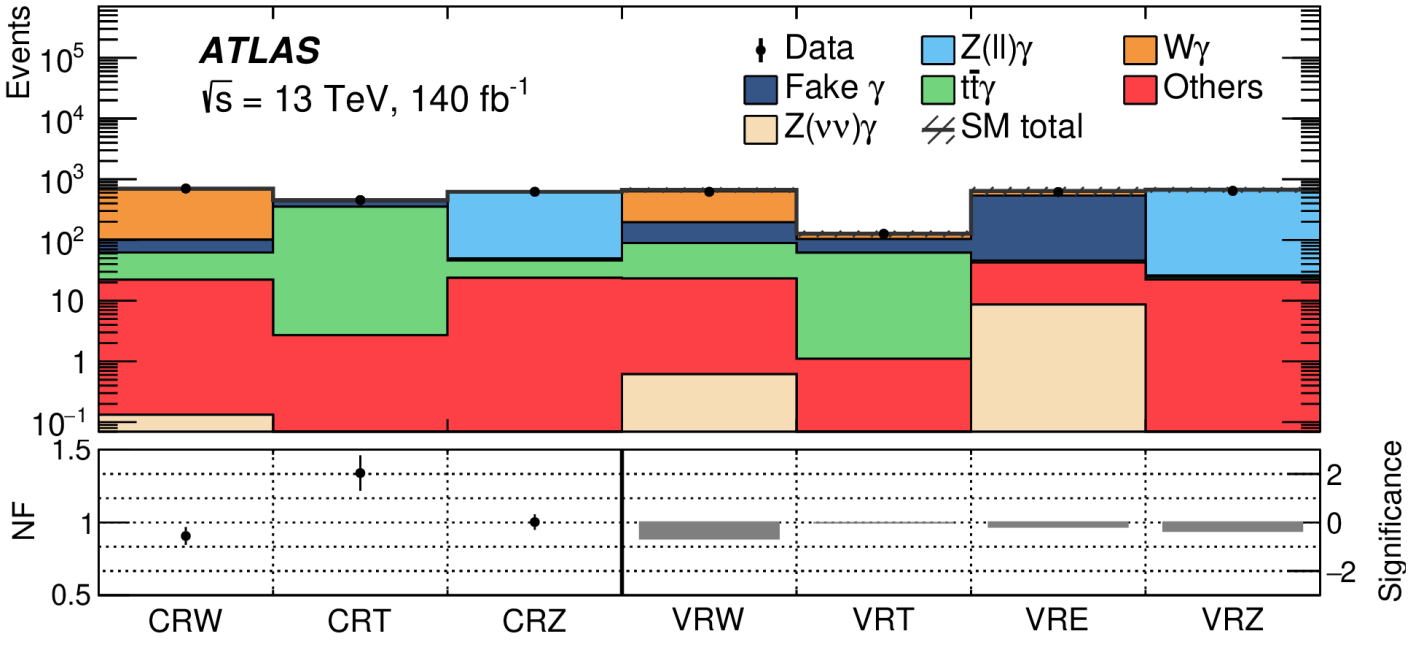

ATL-PHYS-PUB-2024-014

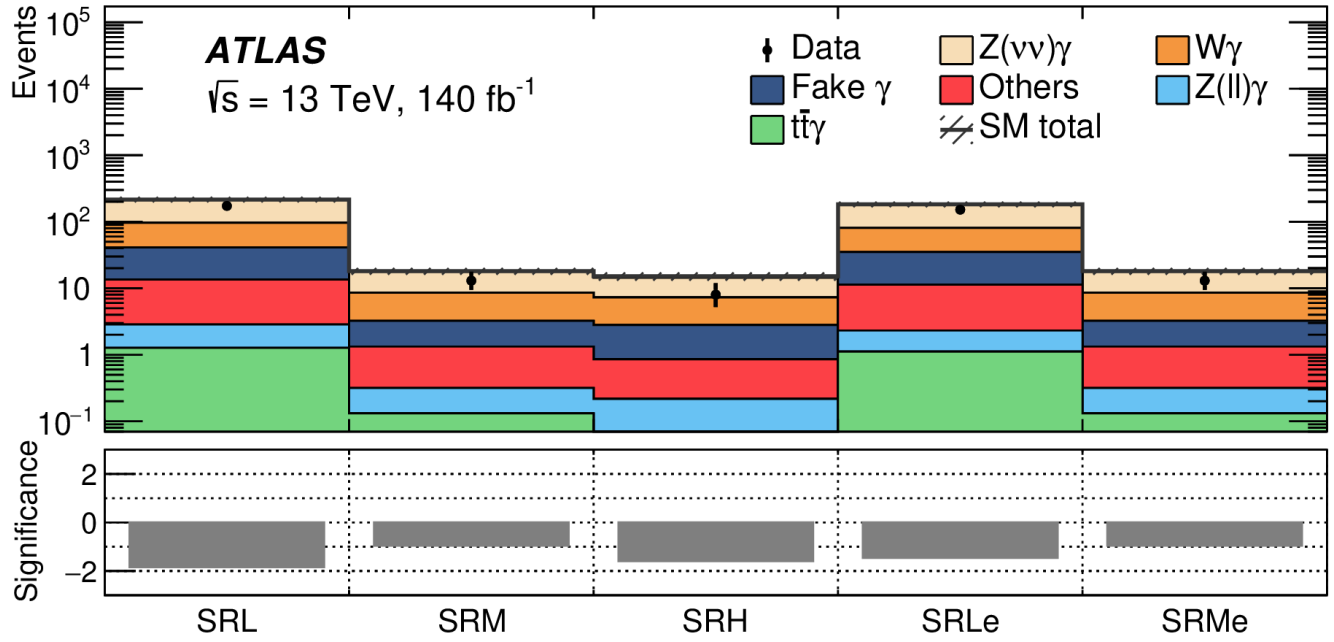
# Higgsinos to photon & gravitino

## Trigger on photon $E_T$>140 GeV

- MET > 200 GeV, at least 1 photon and 1 jet
- Backgrounds constrained in control regions for Wγ, ttγ, and Z→νν
- 5 signal regions in MET and MET significance

JHEP 04 (2026) 150, arXiv:2511.21240



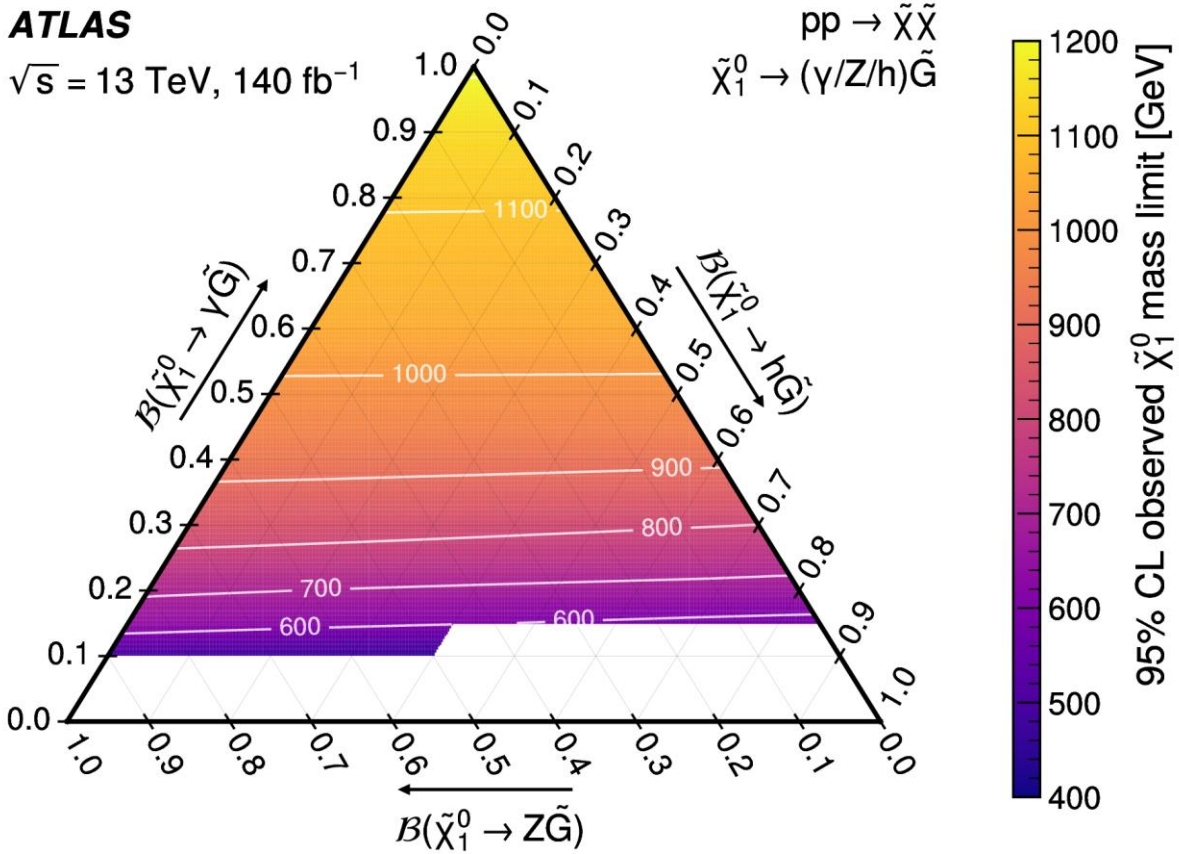



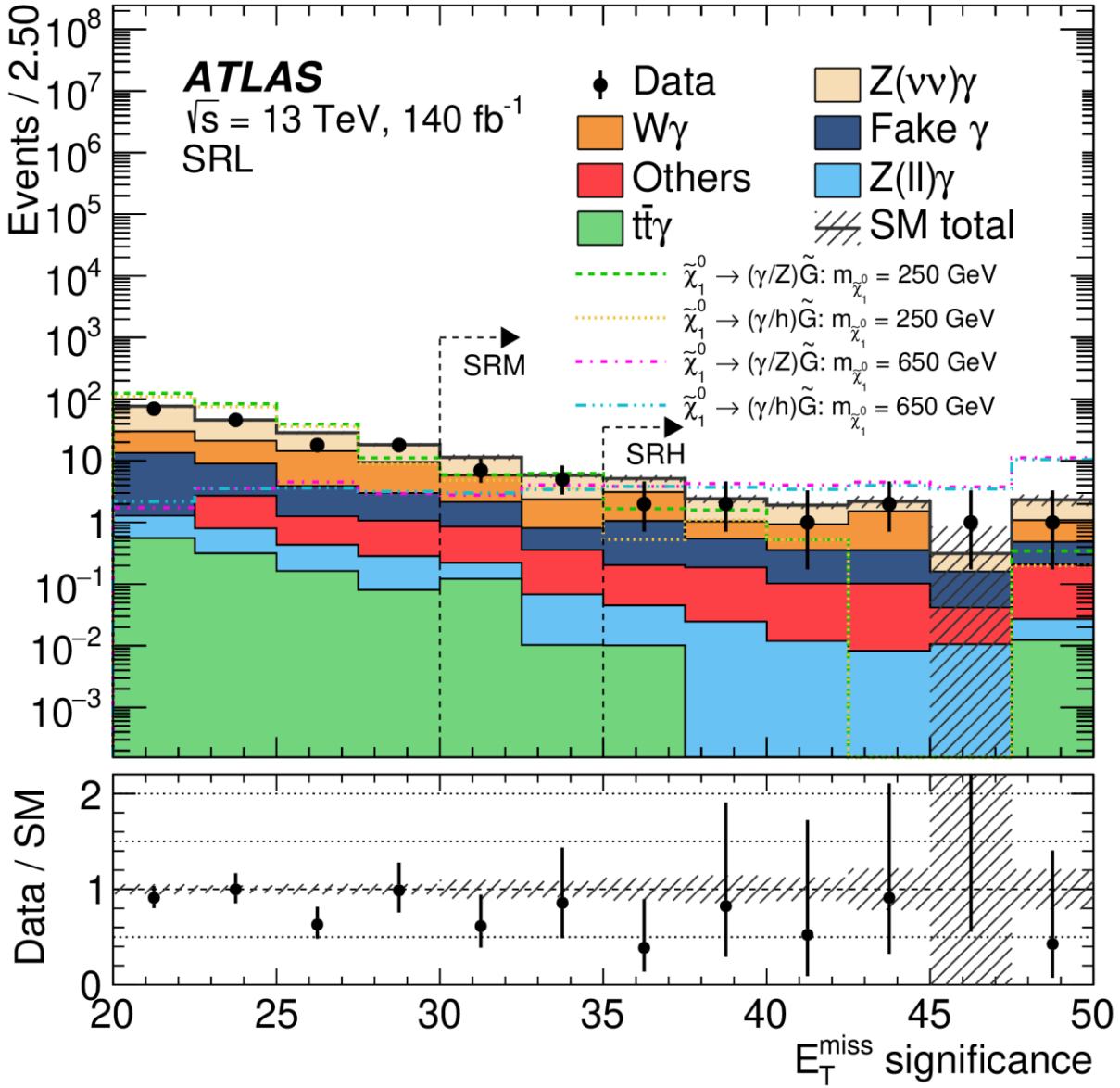
# Higgsinos to photon and gravitino

## No significant excess observed

- Limits set up to 1200 GeV

JHEP 04 (2026) 150, arXiv:2511.21240

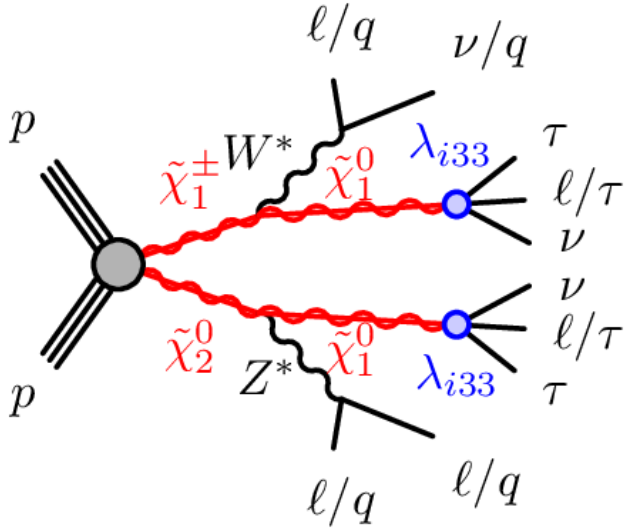


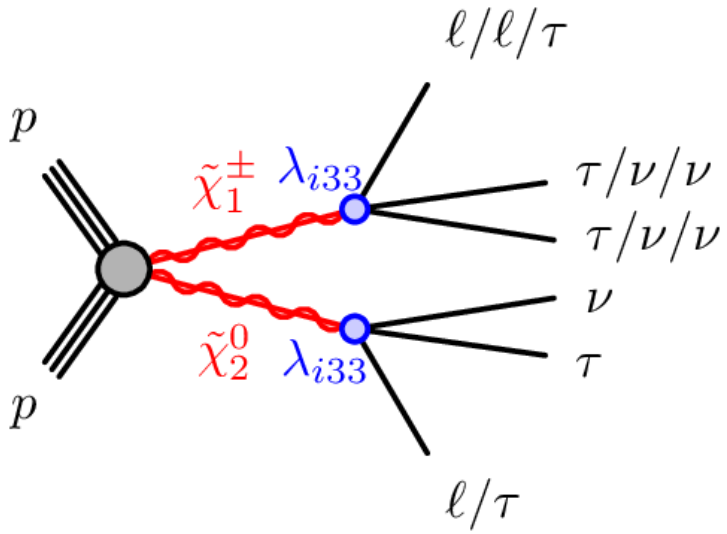
# Higgsinos with R-Parity violating decays

- Exclusion limits for 6 baryon number or lepton number violating couplings by reinterpretation of 13 ATLAS analyses
- In this talk, showing results for Higgsino pair production with $\Delta m$=0.25 GeV and RPV couplings $\lambda_{133}$ and $\lambda_{233}$

**LSP decay**




**NLSP decay**




**$N_2$ decay**

arXiv:2603.15007, submitted to JHEP

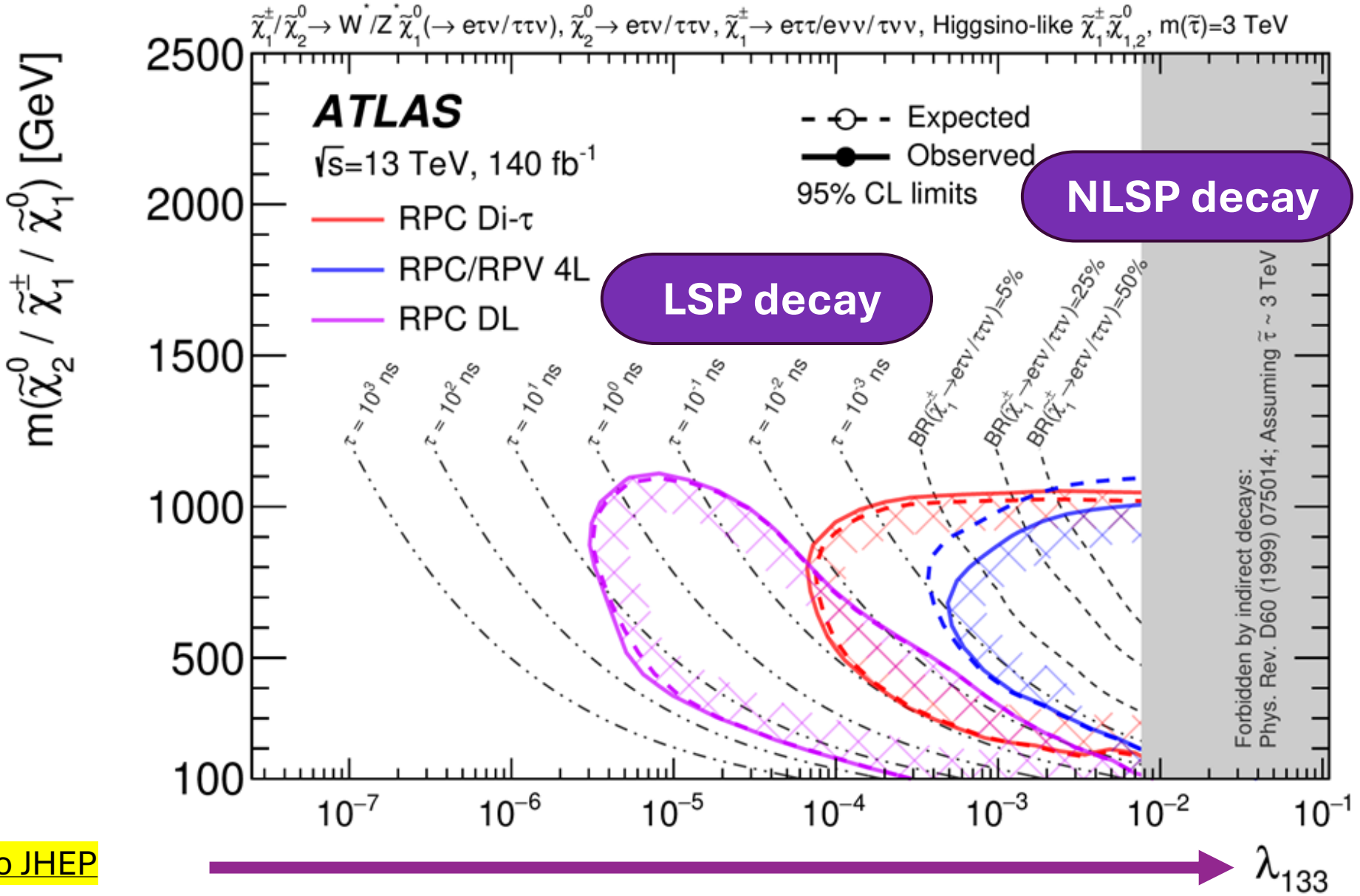
$\lambda_{i33}$

# Higgsinos with R-Parity violating decays

**Electrons and taus**

- 4 leptons
- 2 tau leptons
- Displaced lepton

**Higgsino limits up to 1100 GeV over wide range of $\lambda_{133}$**



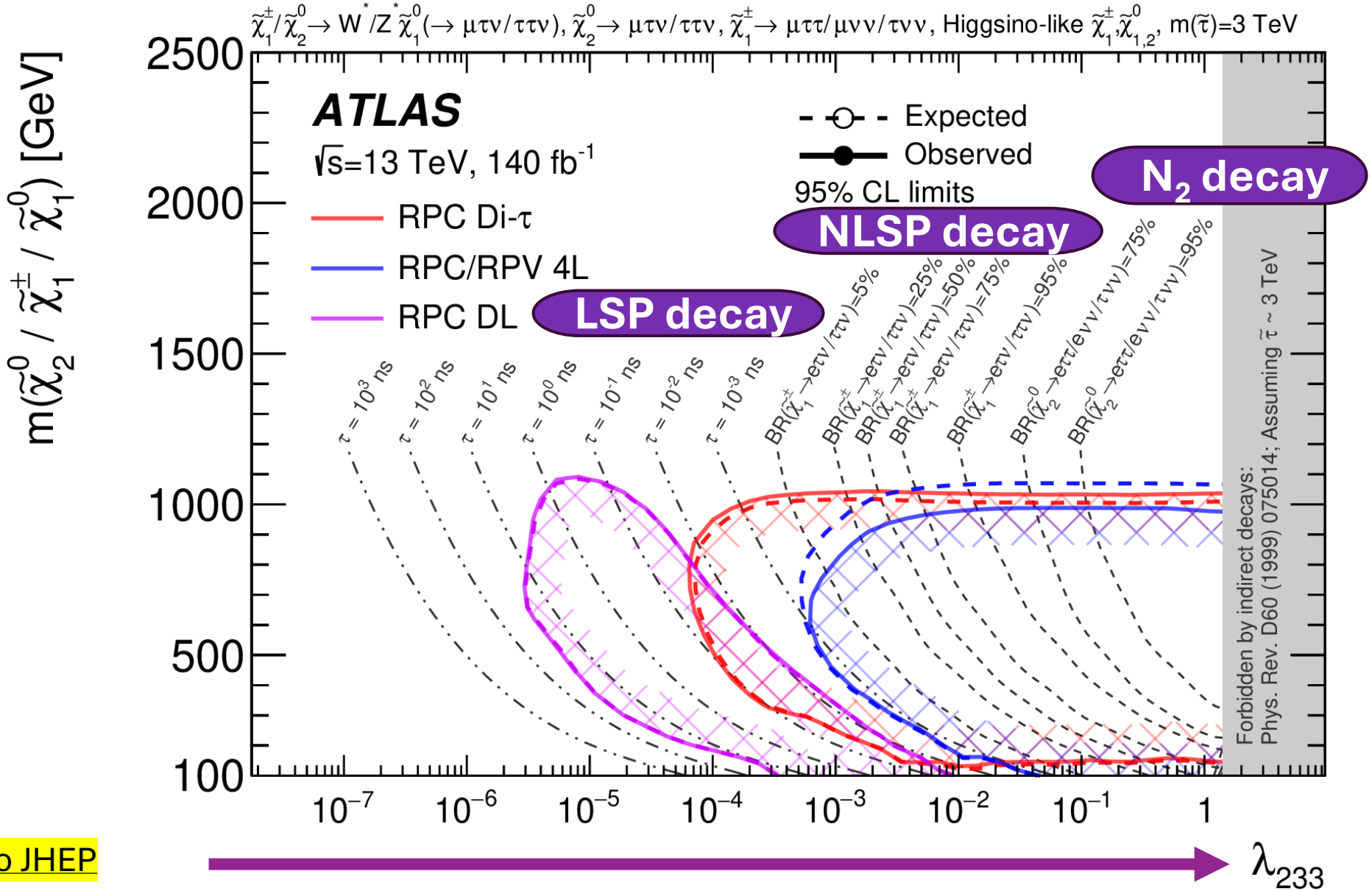

arXiv:2603.15007, submitted to JHEP

# Higgsinos with R-Parity violating decays

**Muons and taus**

- 4 leptons
- 2 tau leptons
- Displaced lepton

**Higgsino limits up to 1100 GeV over wide range of $\lambda_{233}$**



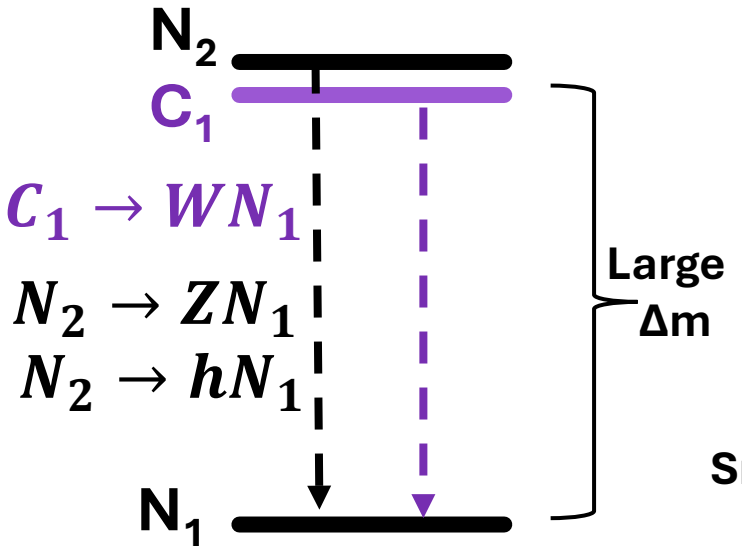

arXiv:2603.15007, submitted to JHEP

# Summary

**ATLAS has explored "uncharted waters" with new challenging experimental signatures & reinterpretations to search for electroweak SUSY**

**ATLAS is looking forward to results with Run 3 data and to HL-LHC in 2030's**

Wino Bino
Stable N1

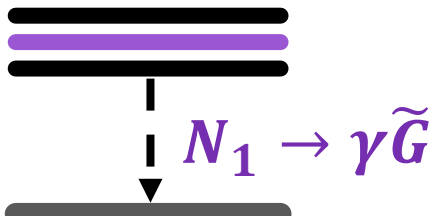



Higgsino triplet
Stable N1

arXiv:2511.20042,
submitted to JHEP

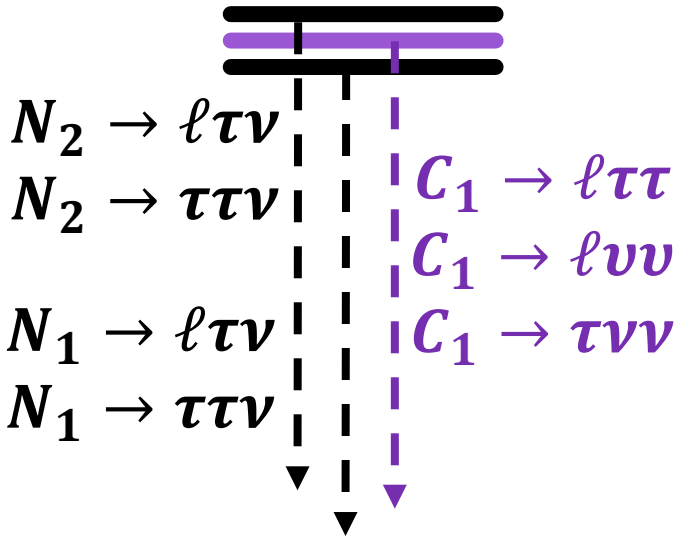

Gravity GMSB
Unstable N1

JHEP 04 (2026) 150
arXiv:2511.21240




RPV
Unstable N1

arXiv:2603.15007
submitted to JHEP



# References for each slide

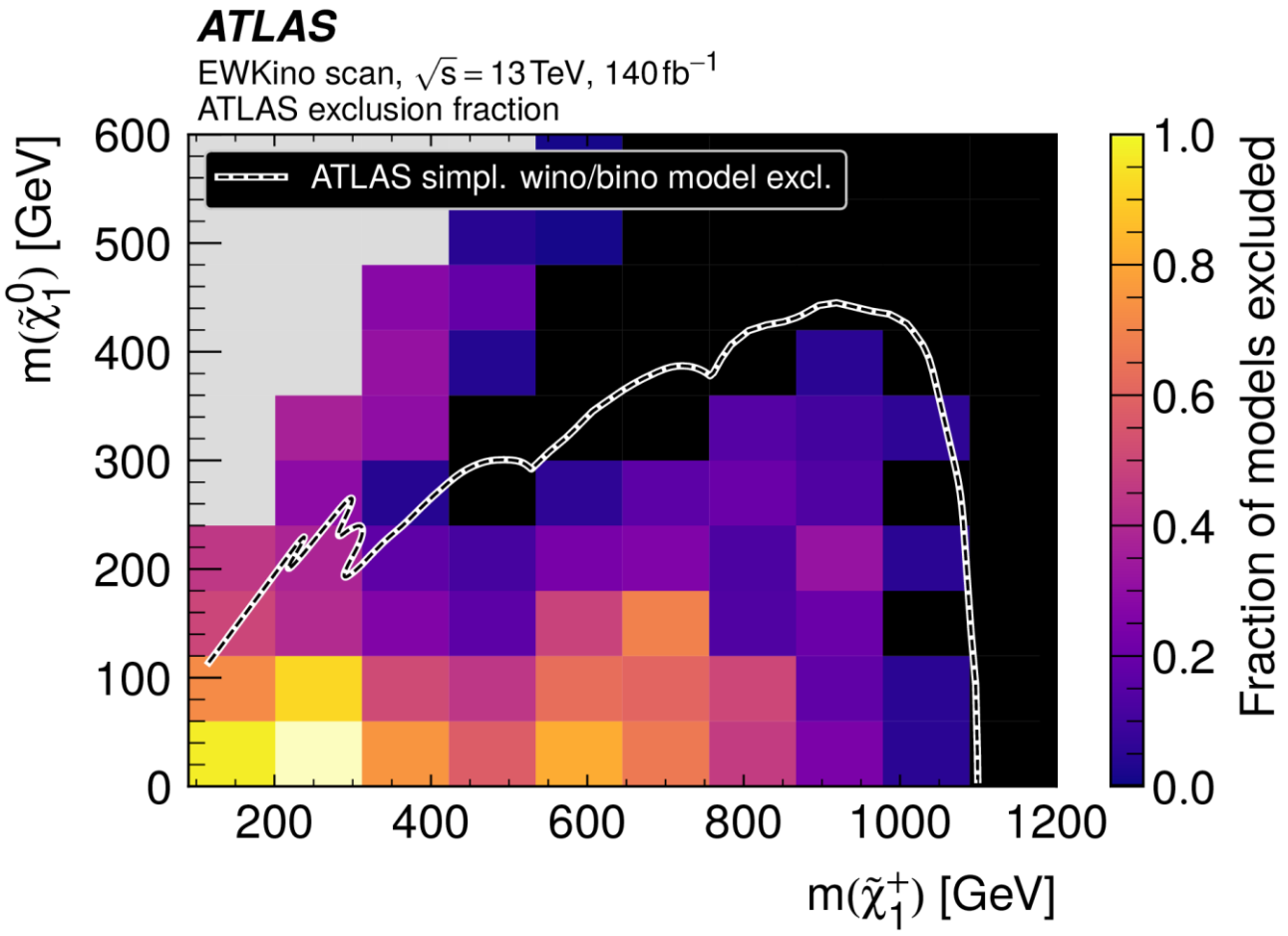
References for figures and results in talk (also on each slide)

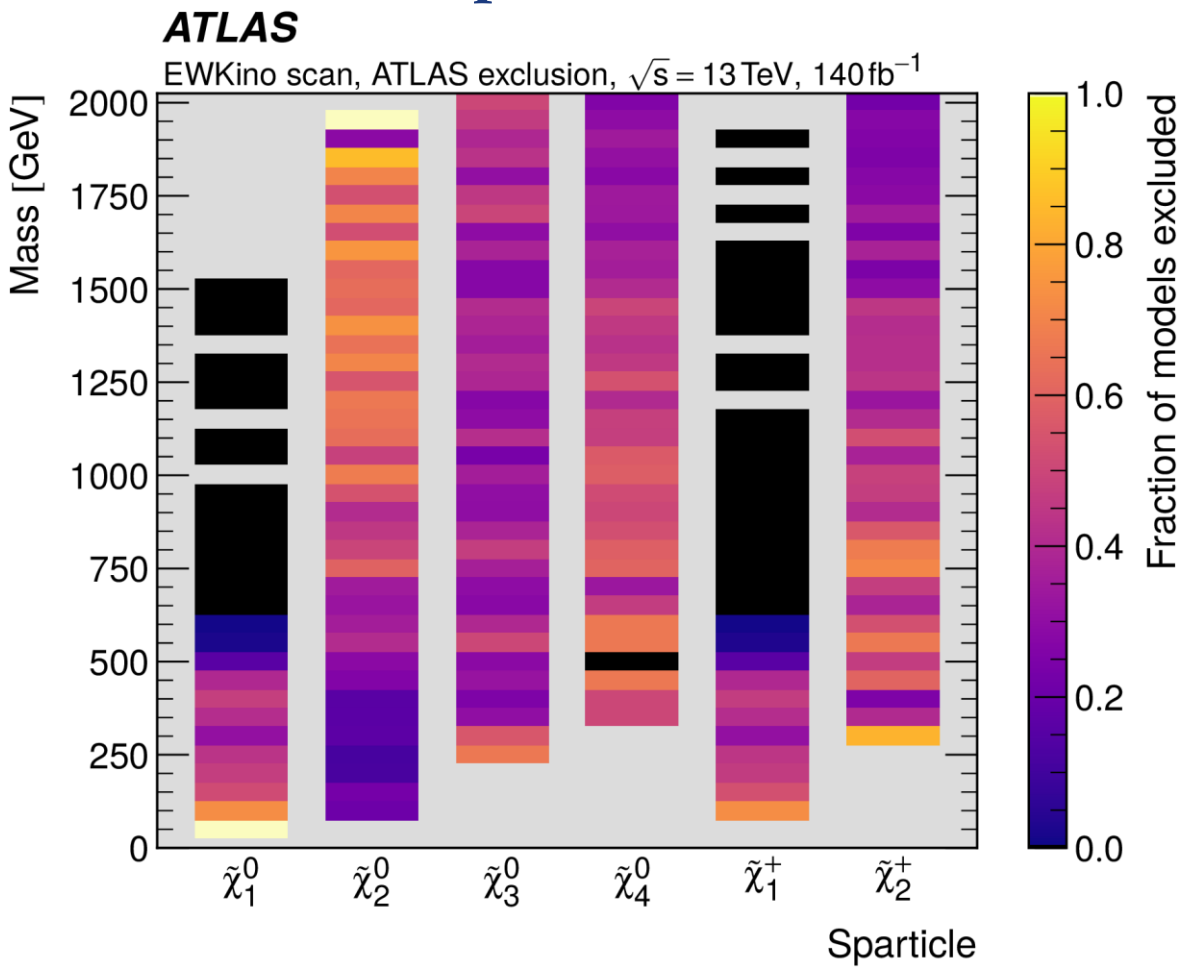
- Slide 2: Production cross sections
  - Phys. Rep. 1116 (2025) 261-300, arXiv:2403.02455
- Slide 4: Disappearing track graphic
  - JHEP 06 (2018) 022, arXiv:1712.02118
- Slide 5 &15: 2024 summary plots
  - ATL-PHYS-PUB-2024-014
- Slide 5 & 6: Compressed Higgsino first search with displaced charged pion 2024
  - Phys. Rev. Lett. 132 (2024) 221801 arXiv:2401.14046
- Slides 7-14: Compressed Higgsino lepton+track and displaced charged pion with NNs 2025
  - arXiv:2511.20042, submitted to JHEP
- Slides 15, 16, 17: EWK SUSY with photons and jets for Higgsino to photon and gravitino
  - JHEP 04 (2026) 150 arXiv:2511.21240
- Slides 18, 19, 20: RPC to RPV reinterpretation for Higgsinos with RPV decays
  - arXiv:2603.15007, submitted to JHEP
- Backup:
  - Run 2 C1N1 large Δm limits Phys. Rev. Lett. 133 (2024) 031802 arXiv:2402.08347
  - pMSSM reinterpretation JHEP 05 (2024) 106, arXiv:2402.01392
  - 2026 new disappearing track briefing https://atlas.cern/Updates/Briefing/Disappearing-Track

# pMSSM SUSY Run 2

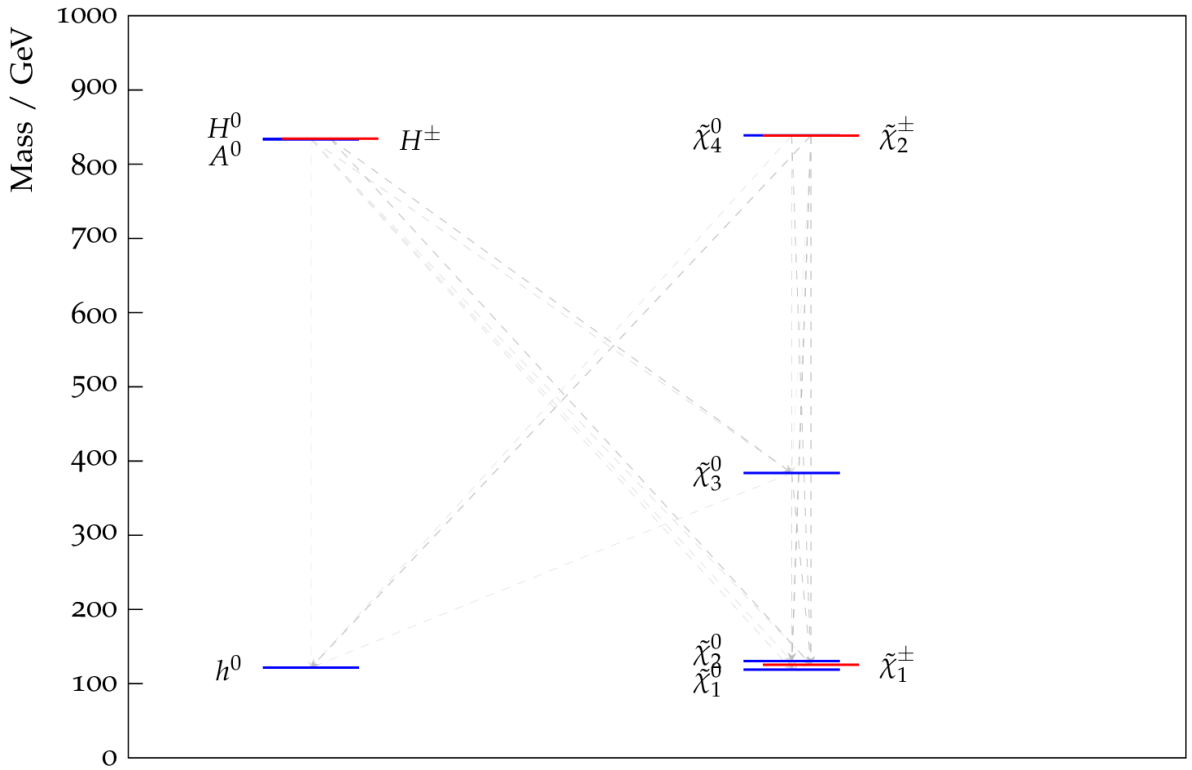
JHEP 05 (2024) 106, arXiv:2402.01392

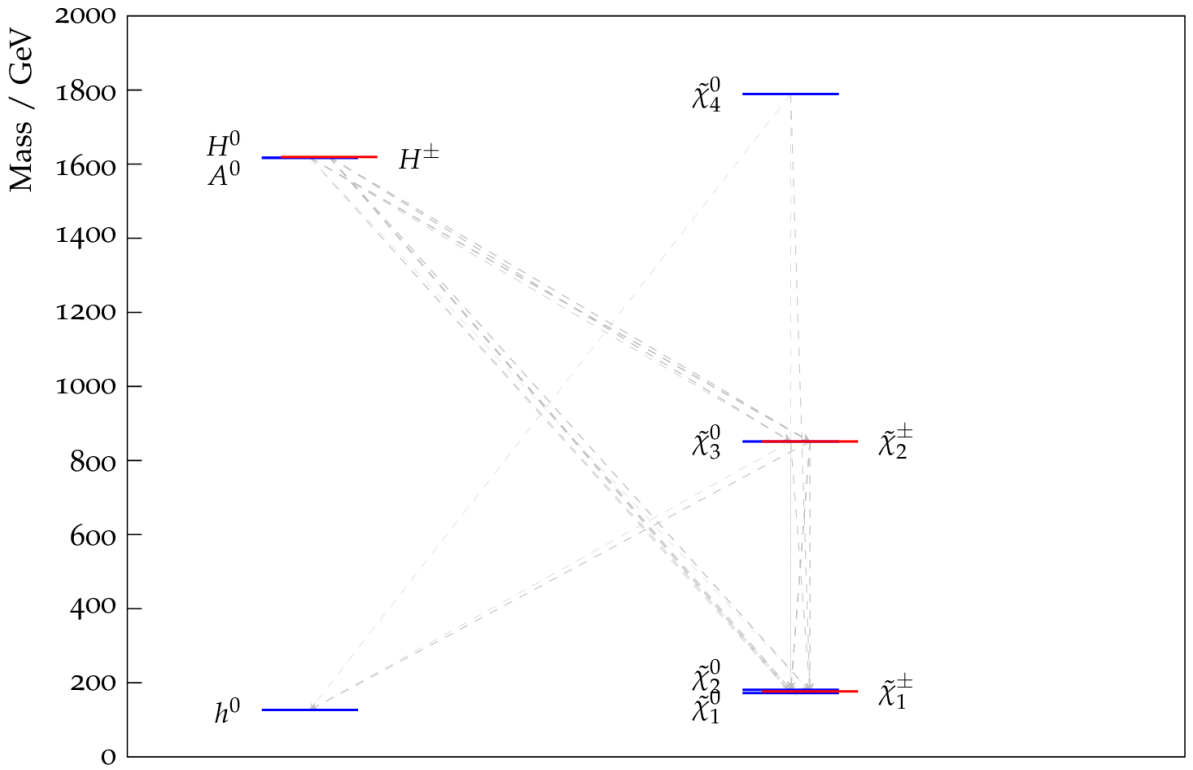
- Simplified models have their limits…exclusion not as deep as it may appear!
- On the other hand, cascade decays from higher mass states do give some exclusion for compressed SUSY beyond limits from simplified models



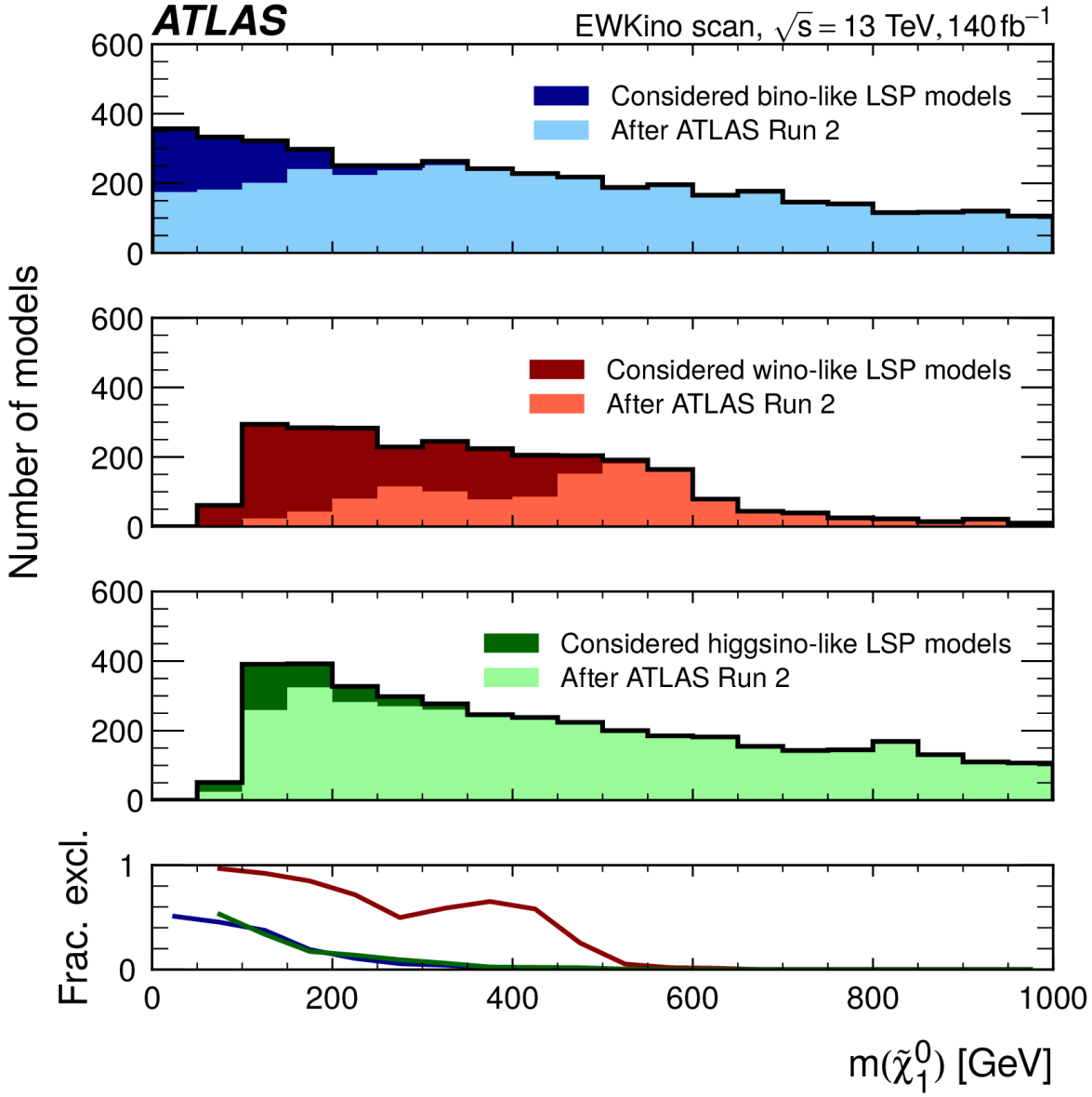



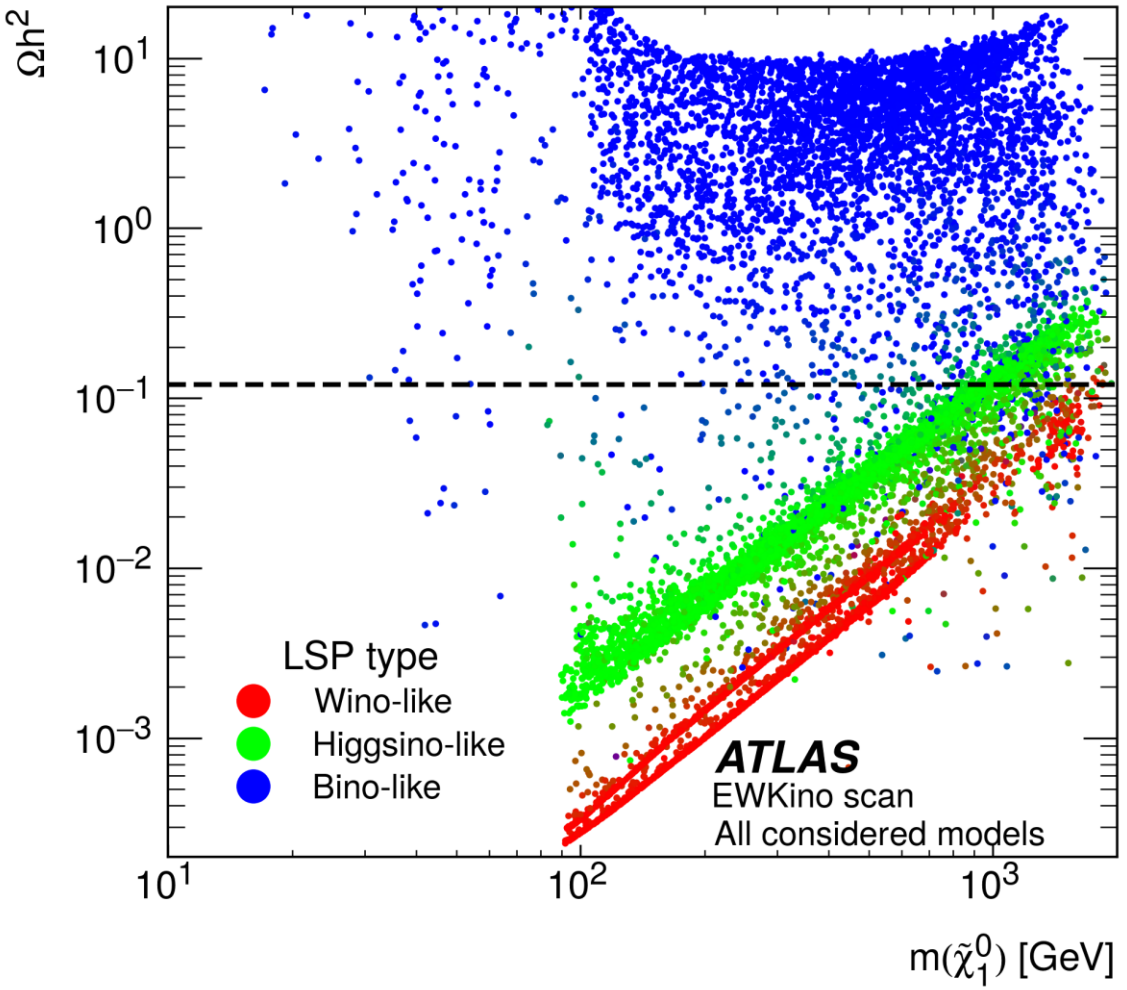
# Example of Higgsino models still allowed in pMSSM scan in 2024



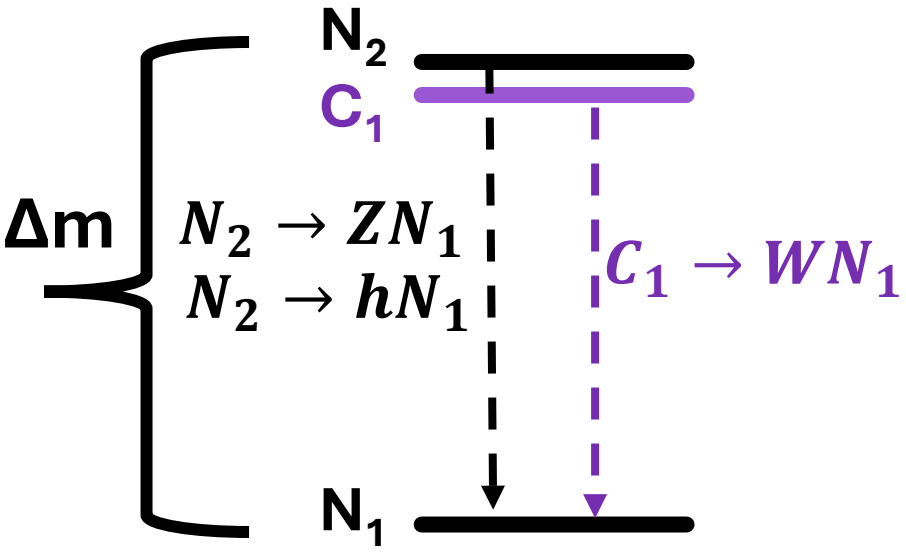
# More pMSSM plots

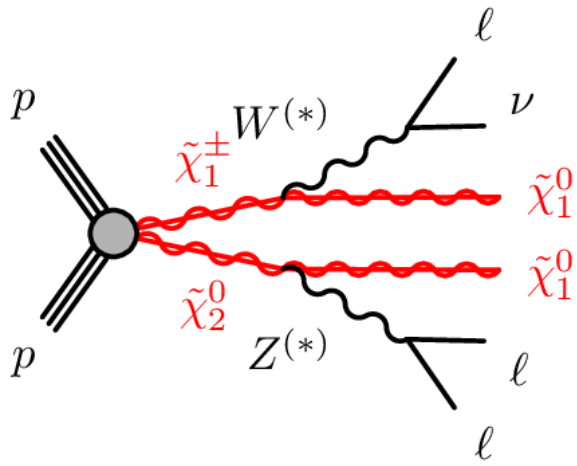


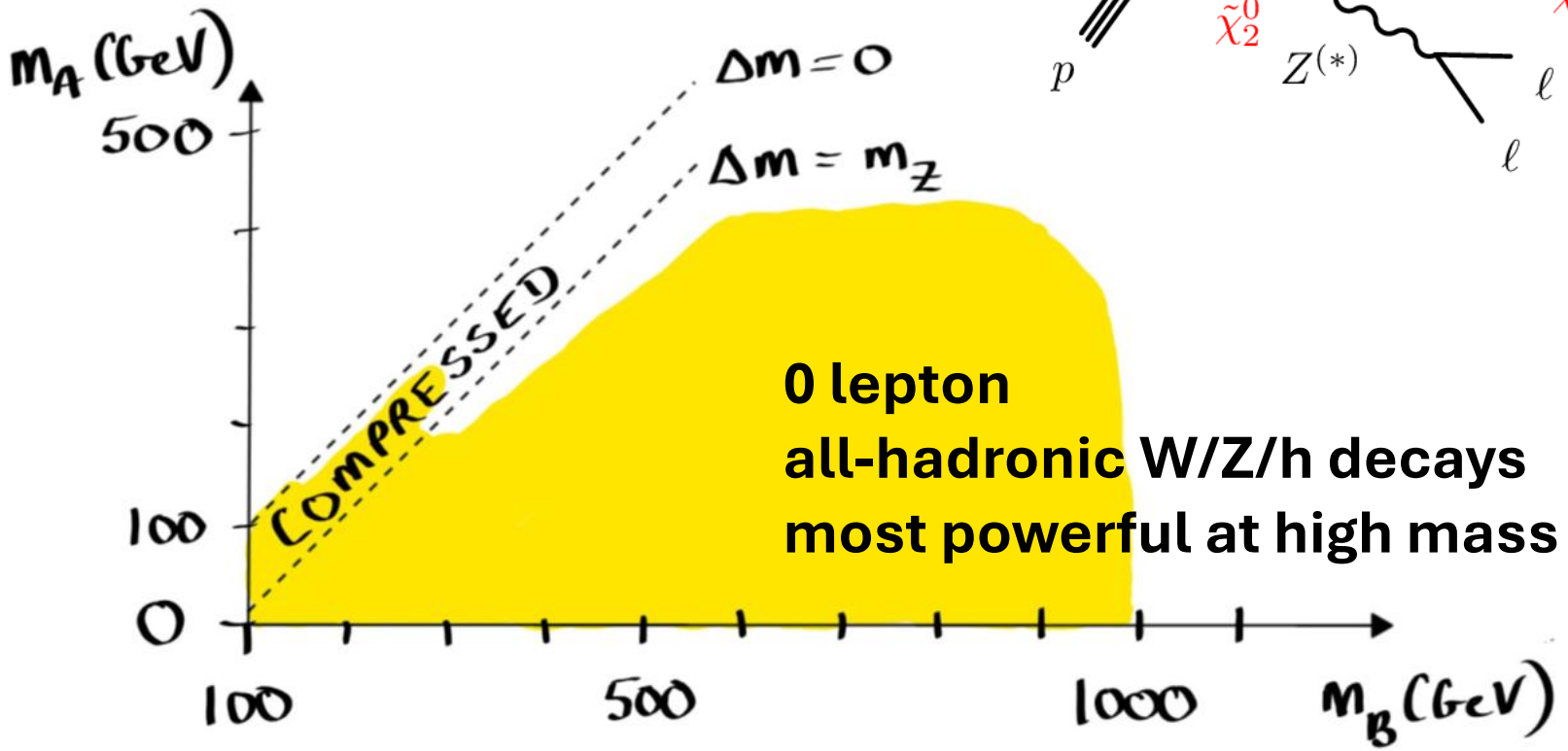



# Introduction: limit plots for large Δm

- Search results presented in 2D mass plane as exclusion limits at 95% CL

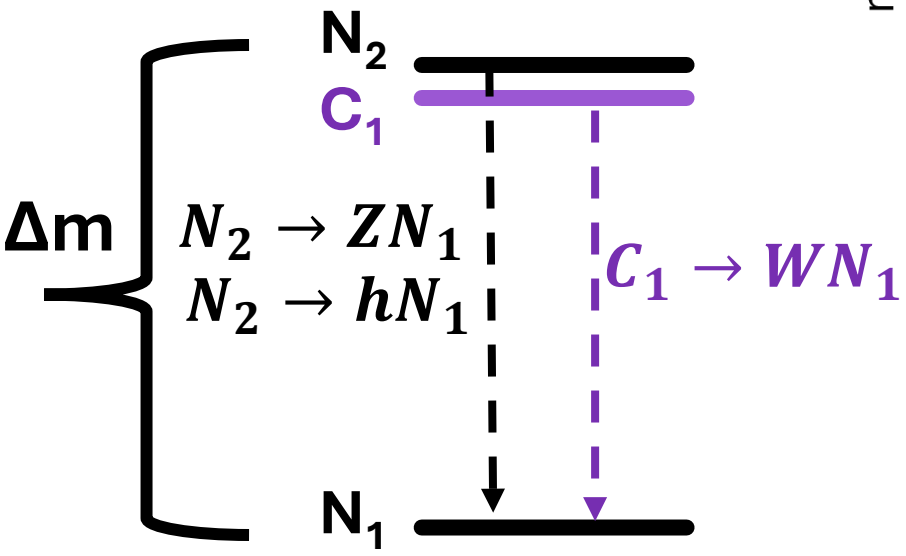


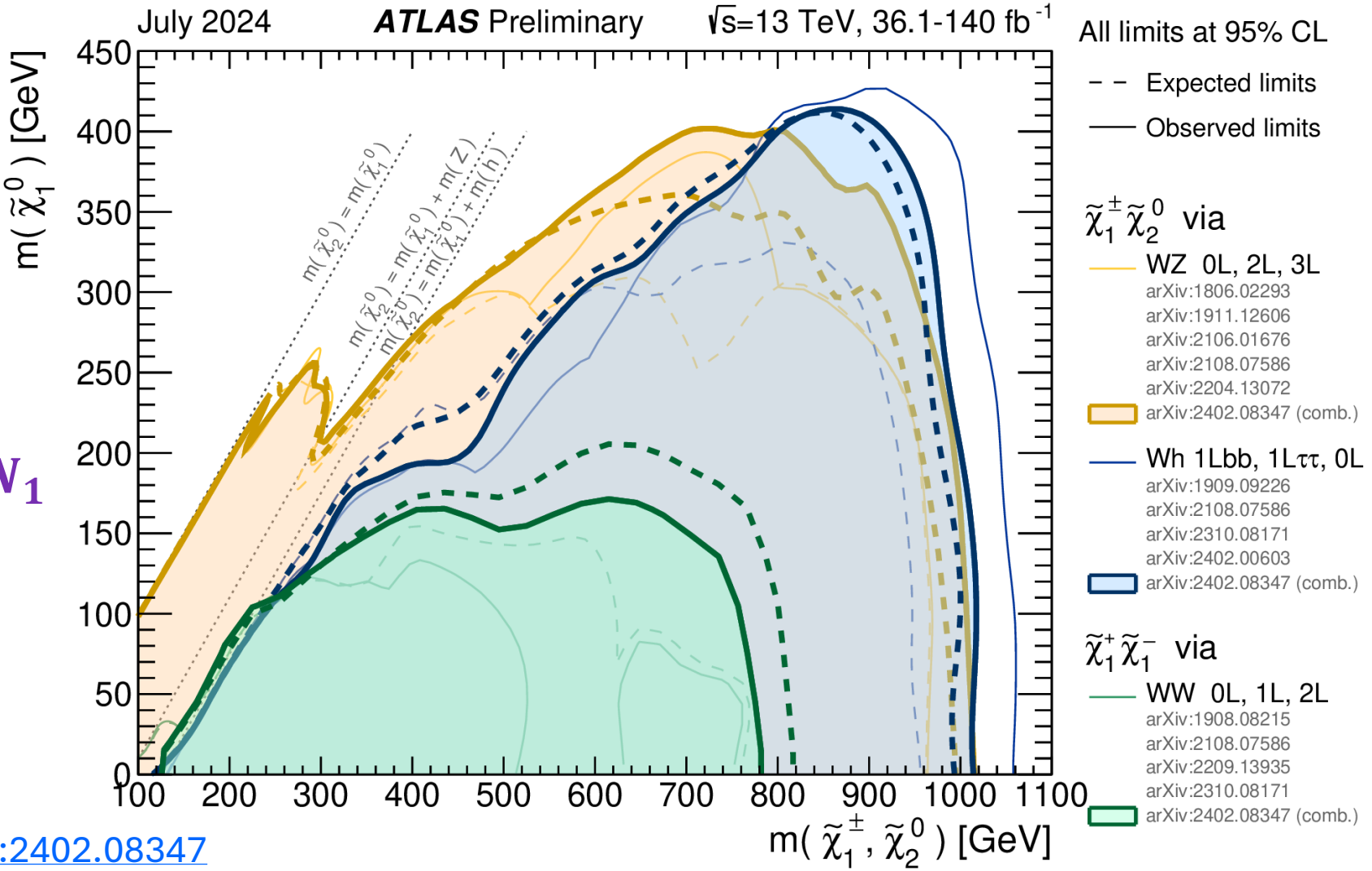



# Introduction: limit plots for large Δm

- Search results presented in 2D mass plane as exclusion limits at 95% CL




Phys. Rev. Lett. 133 (2024) 031802 arXiv:2402.08347

# Higgsinos to γ/Z/h and gravitino

- Cross section and BR plots