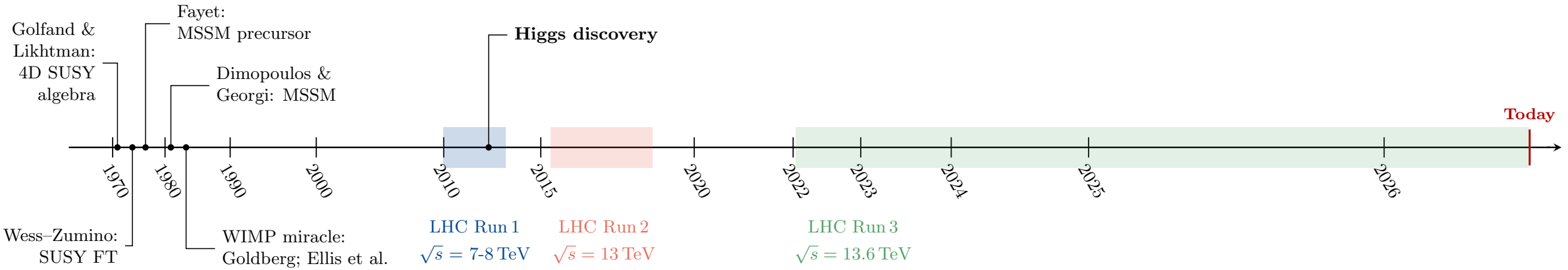
Searches for Supersymmetry with the ATLAS and CMS experiments

Christian Ohm, obo the ATLAS and CMS Collaborations, Moriond EW, March 15-22

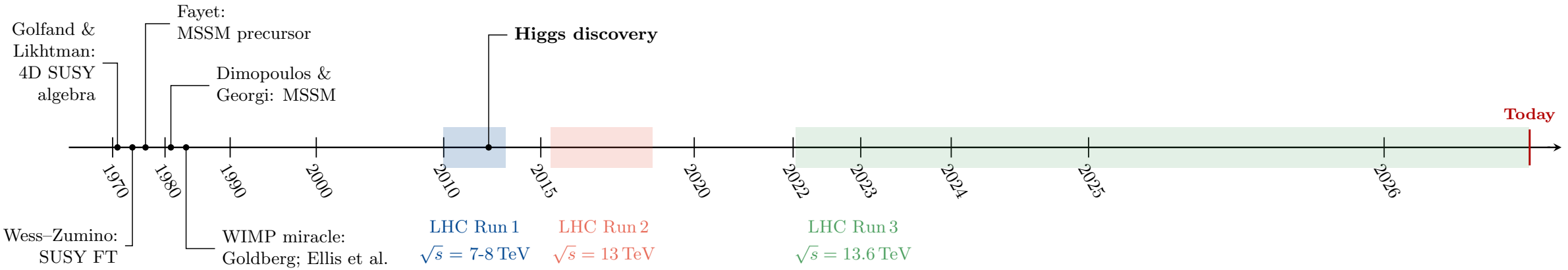
General motivation and status of SUSY

- SUSY argued to be last possible additional symmetry, and SUSY models attractive since they can
  - Alleviate ***fine-tuning of Higgs mass*** (naturalness)
  - Improve ***unification of forces*** at GUT scale
  - Provide particles that can make up the ***dark matter***



General motivation and status of SUSY

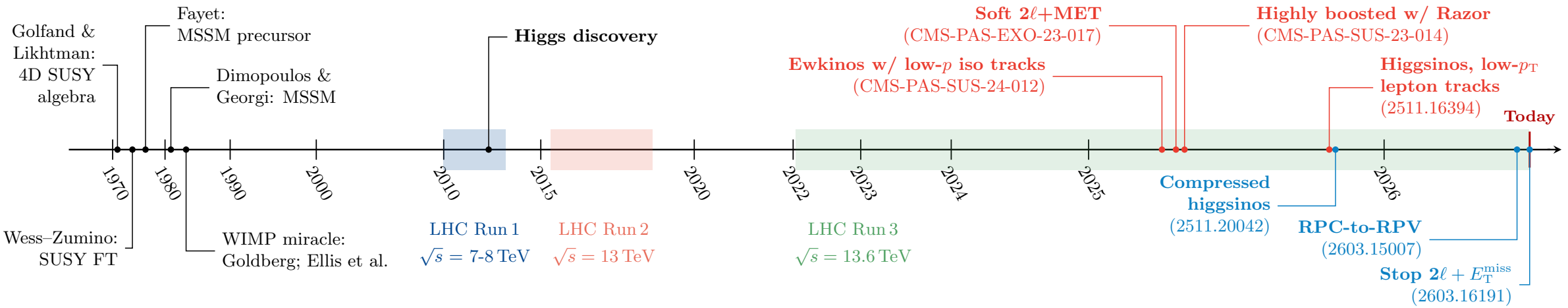
- SUSY argued to be last possible additional symmetry, and SUSY models attractive since they can
  - Alleviate ***fine-tuning of Higgs mass*** (naturalness)
  - Improve ***unification of forces*** at GUT scale
  - Provide particles that can make up the ***dark matter***



- Run 1: Inclusive/general searches produced powerful exclusion limits

General motivation and status of SUSY

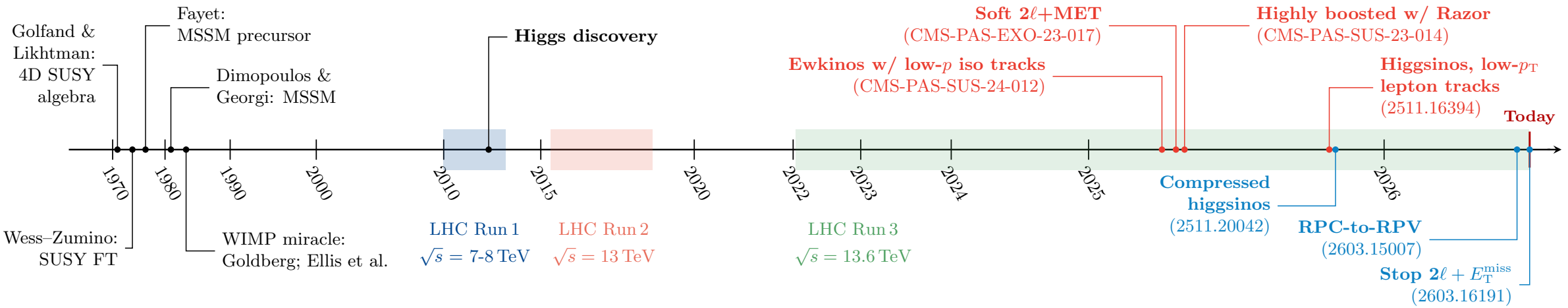
- SUSY argued to be last possible additional symmetry, and SUSY models attractive since they can
  - Alleviate ***fine-tuning of Higgs mass*** (naturalness)
  - Improve ***unification of forces*** at GUT scale
  - Provide particles that can make up the ***dark matter***



- Run 1: Inclusive/general searches produced powerful exclusion limits
- Now: methodology-driven efforts targeting tricky parts of parameter space
  - LLPs, compressed scenarios + improvements from innovative reconstruction & ML/AI techniques

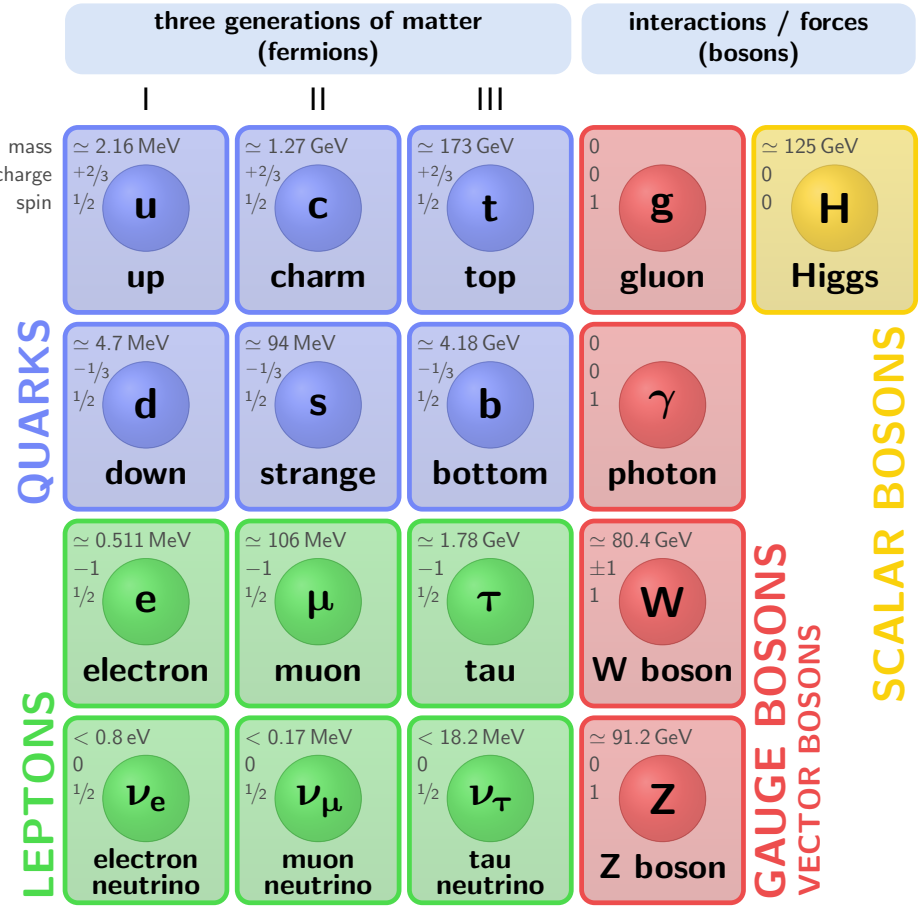
General motivation and status of SUSY

- SUSY argued to be last possible additional symmetry, and SUSY models attractive since they can
  - Alleviate ***fine-tuning of Higgs mass*** (naturalness)
  - Improve ***unification of forces*** at GUT scale
  - Provide particles that can make up the ***dark matter***



- Run 1: Inclusive/general searches produced powerful exclusion limits
- Now: methodology-driven efforts targeting tricky parts of parameter space
  - LLPs, compressed scenarios + improvements from innovative reconstruction & ML/AI techniques
- More SUSY tomorrow: NP with photons, DVs + unconv. sign., ATLAS wildcard

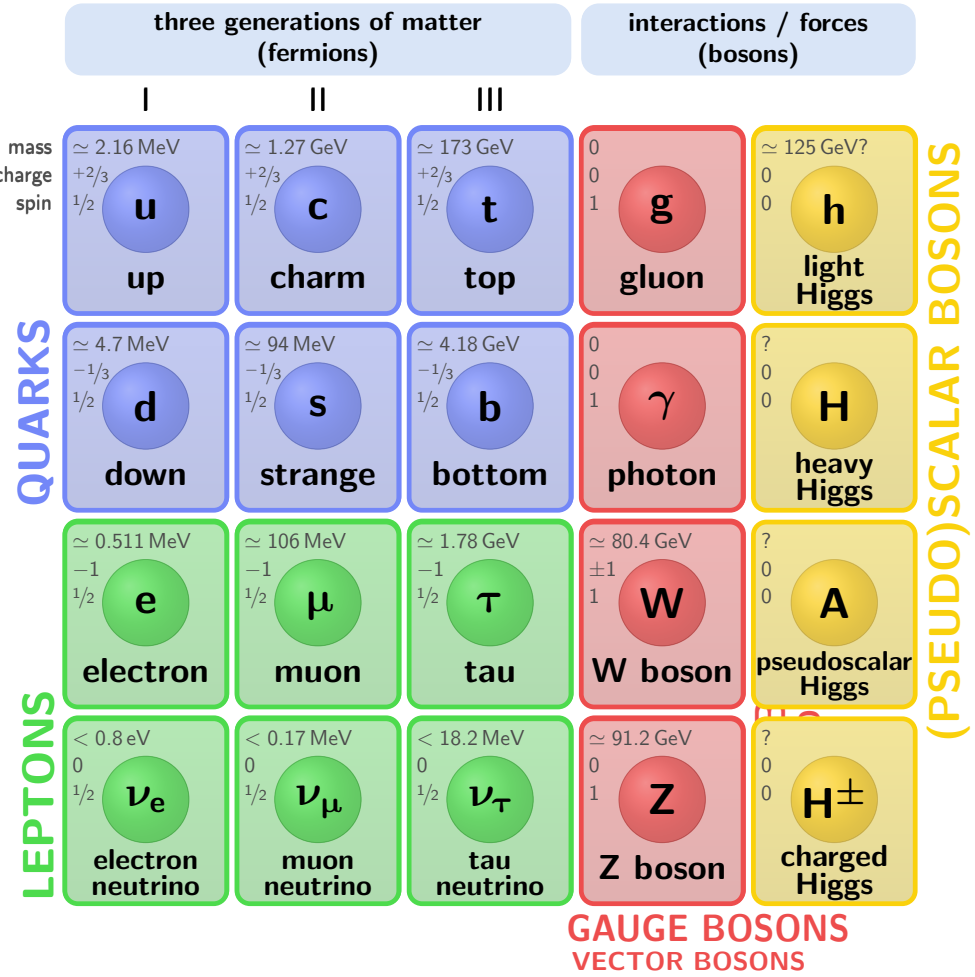
Particles in MSSM



TiKZ figs by I. Neutelings

Particles in MSSM

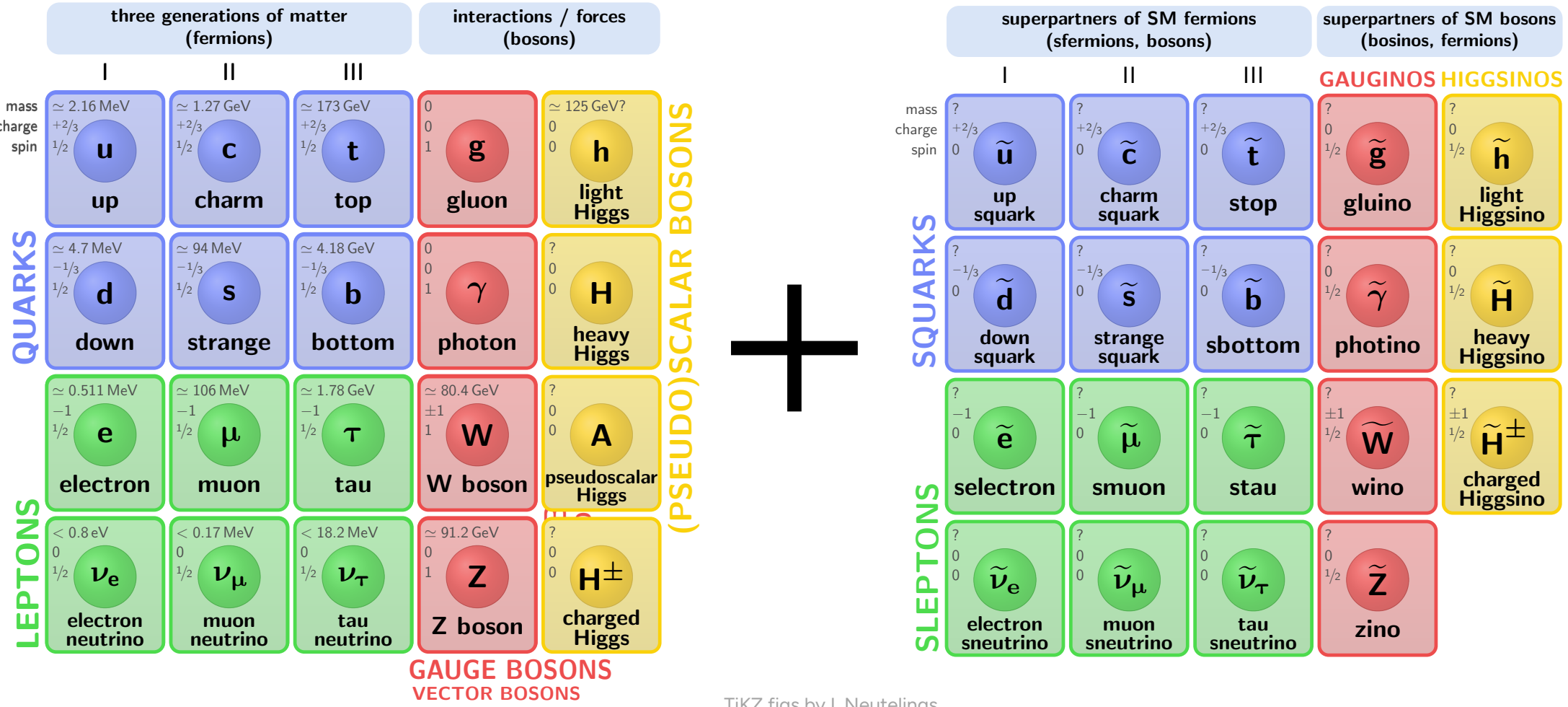
- Extended Higgs sector (2HDM) + Symmetry: fermions ↔ bosons



TiKZ figs by I. Neutelings

Particles in MSSM

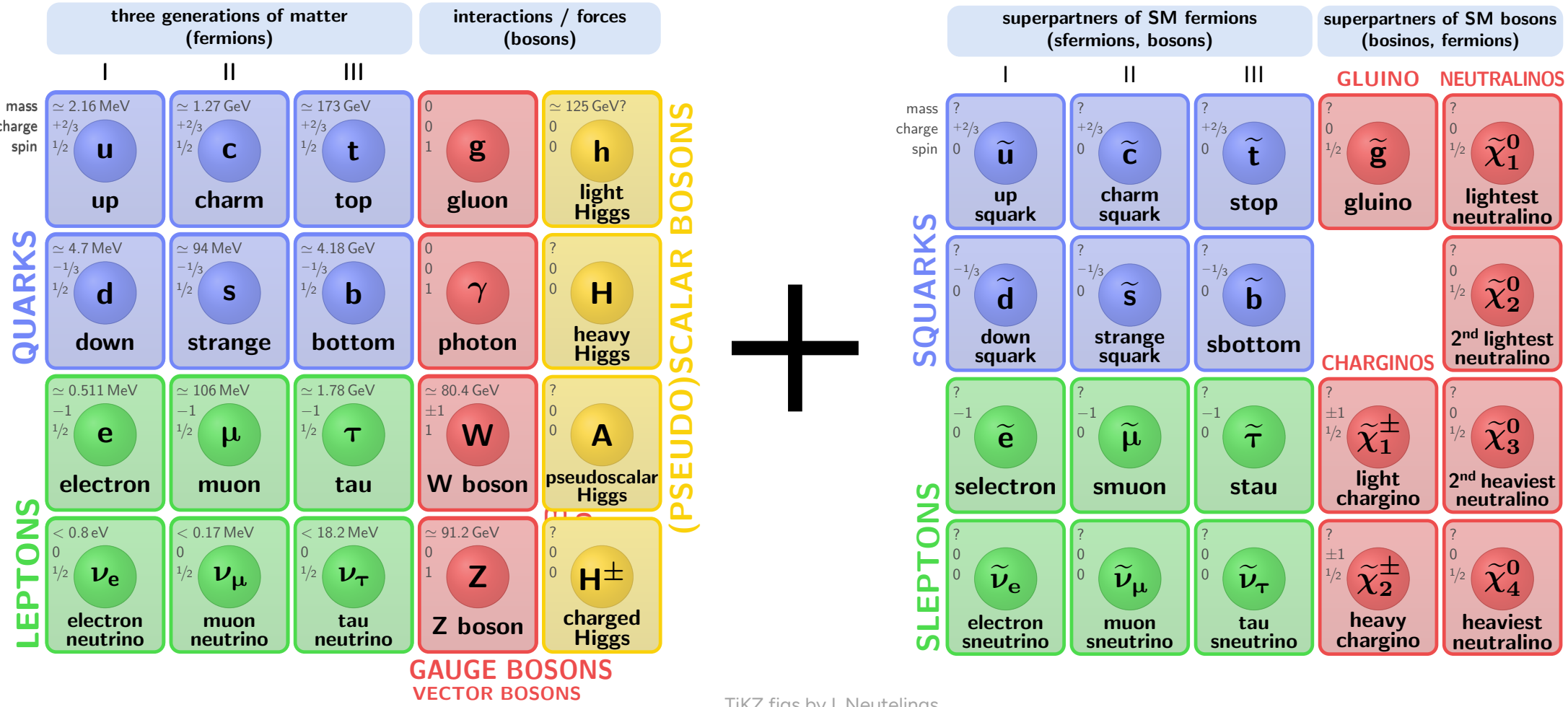
- Extended Higgs sector (2HDM) + Symmetry: fermions ↔ bosons
- Wino, Higgsino, Bino mix to form charginos $\tilde{\chi}^{\pm}$ and neutralinos $\tilde{\chi}^{0}$



TiKZ figs by I. Neutelings

Particles in MSSM

- Extended Higgs sector (2HDM) + Symmetry: fermions ↔ bosons
- Wino, Higgsino, Bino mix to form charginos $\tilde{\chi}^{\pm}$ and neutralinos $\tilde{\chi}^{0}$



TiKZ figs by I. Neutelings

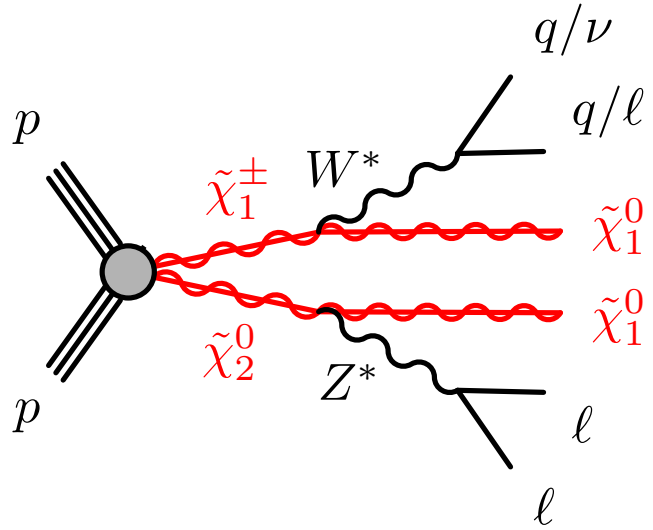
Compressed electroweakinos

- Light Higgsinos (low μ) good for naturalness

  m_H affected by $m_{\tilde{t}}$ at loop-level,
  but μ affects m_H at tree-level

- Lightest SUSY particles become nearly mass-degenerate Higgsinos: $\tilde{\chi}_1^0, \tilde{\chi}_1^\pm, \tilde{\chi}_2^0$

$$\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) \sim \begin{cases} 300 \text{ MeV}, & \text{if pure Higgsino} \\ \mathcal{O}(10 \text{ GeV}), & \text{if } \tilde{W}/\tilde{B} \text{ mixing} \end{cases}$$



Based on TiKZ figs by I. Neutelings

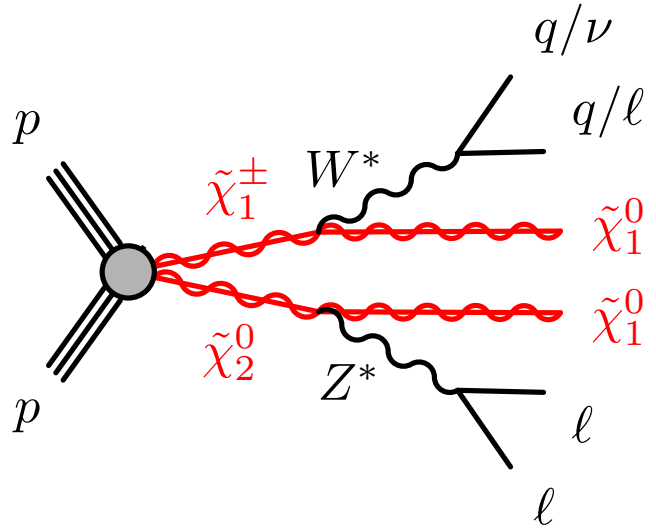
Compressed electroweakinos

- Light Higgsinos (low μ) good for naturalness

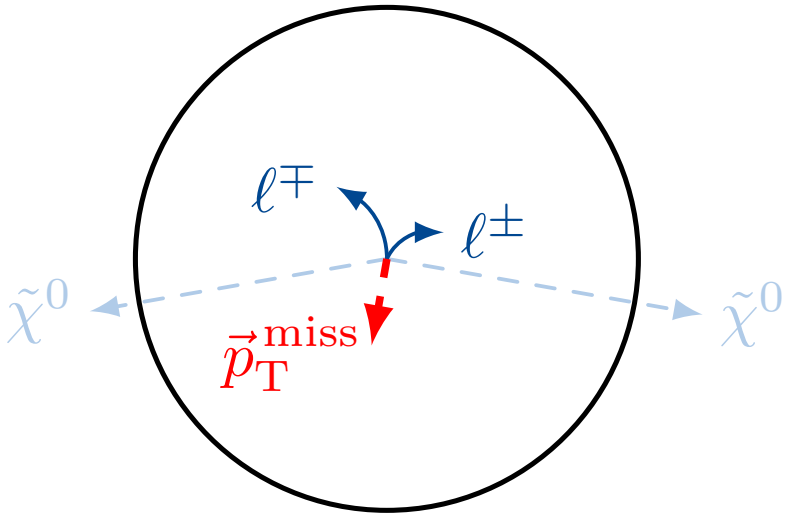
  m_H affected by $m_{\tilde{t}}$ at loop-level,
  but μ affects m_H at tree-level

- Lightest SUSY particles become nearly mass-degenerate Higgsinos: $\tilde{\chi}_1^0, \tilde{\chi}_1^\pm, \tilde{\chi}_2^0$

$$\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) \sim \begin{cases} 300 \text{ MeV}, & \text{if pure Higgsino} \\ \mathcal{O}(10 \text{ GeV}), & \text{if } \tilde{W}/\tilde{B} \text{ mixing} \end{cases}$$



- Signatures: soft leptons or tracks



Based on TiKZ figs by I. Neutelings

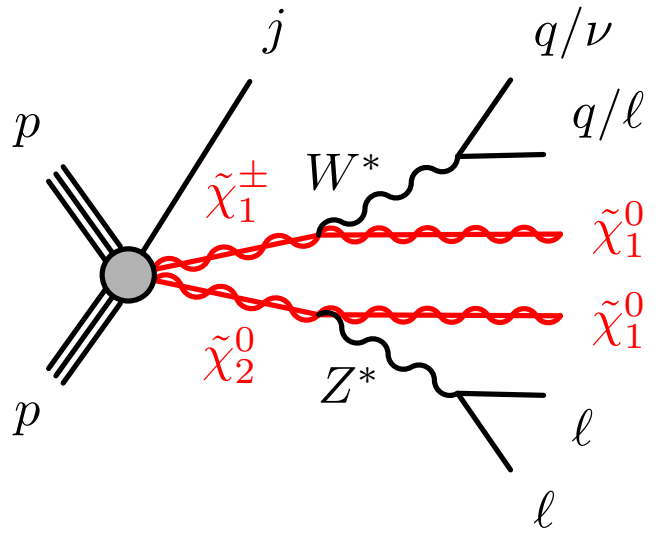
Compressed electroweakinos

- Light Higgsinos (low μ) good for naturalness

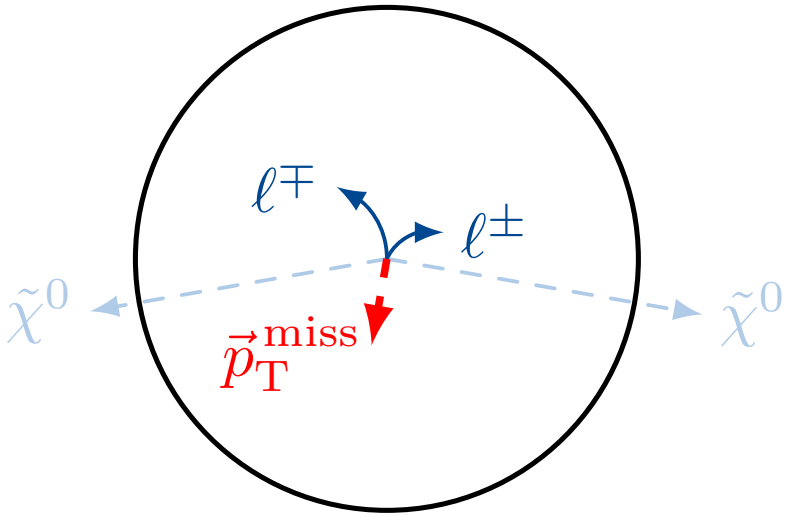
  m_H affected by $m_{\tilde{t}}$ at loop-level,
  but μ affects m_H at tree-level

- Lightest SUSY particles become nearly mass-degenerate Higgsinos: $\tilde{\chi}_1^0, \tilde{\chi}_1^\pm, \tilde{\chi}_2^0$

$$\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) \sim \begin{cases} 300 \text{ MeV}, & \text{if pure Higgsino} \\ \mathcal{O}(10 \text{ GeV}), & \text{if } \tilde{W}/\tilde{B} \text{ mixing} \end{cases}$$



- Signatures: soft leptons or tracks
- Strategy: rely on ISR



Based on TiKZ figs by I. Neutelings

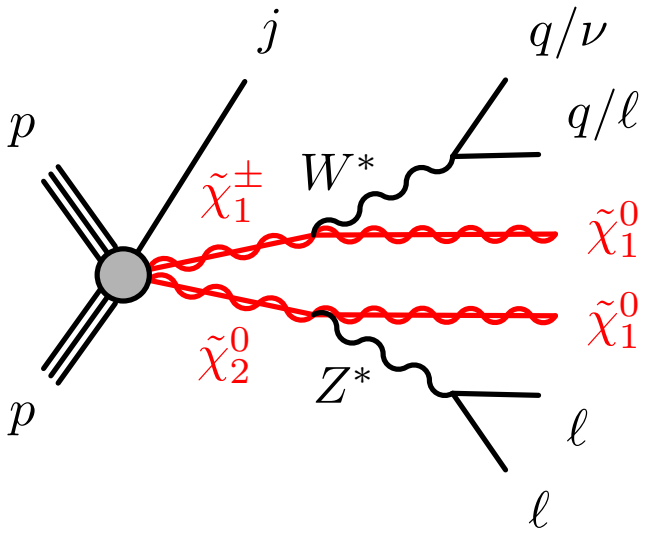
Compressed electroweakinos

- Light Higgsinos (low μ) good for naturalness

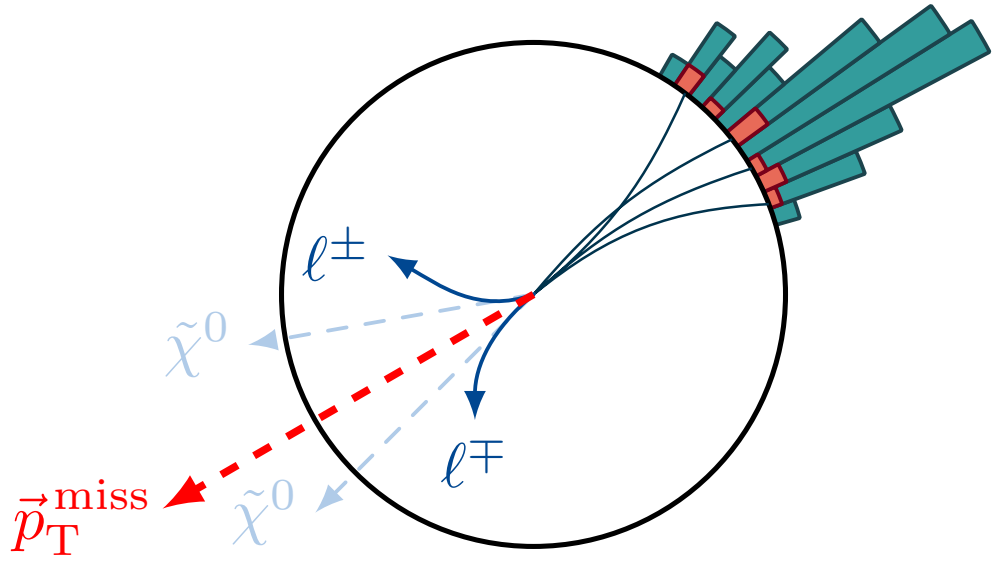
  m_H affected by $m_{\tilde{t}}$ at loop-level,
  but μ affects m_H at tree-level

- Lightest SUSY particles become nearly mass-degenerate Higgsinos: $\tilde{\chi}_1^0, \tilde{\chi}_1^\pm, \tilde{\chi}_2^0$

$$\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) \sim \begin{cases} 300\ \text{MeV}, & \text{if pure Higgsino} \\ \mathcal{O}(10\ \text{GeV}), & \text{if } \tilde{W}/\tilde{B} \text{ mixing} \end{cases}$$



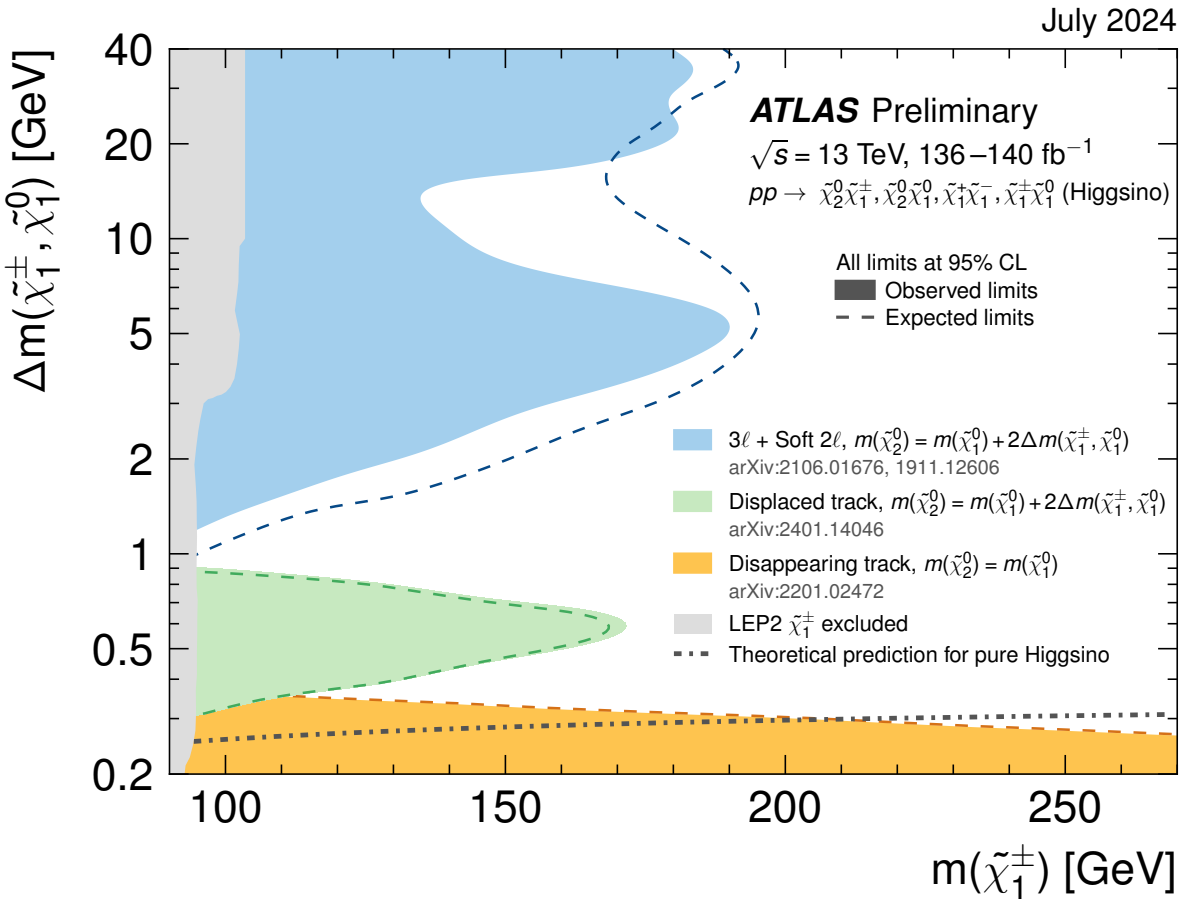
- Signatures: soft leptons or tracks
- Strategy: rely on ISR
  - high-p_T jet and large $E_\mathrm{T}^\mathrm{miss}$ as trigger handle
  - Harder $\tilde{\chi}^0$ decay products due to recoil



Based on TiKZ figs by I. Neutelings

Compressed electroweakinos

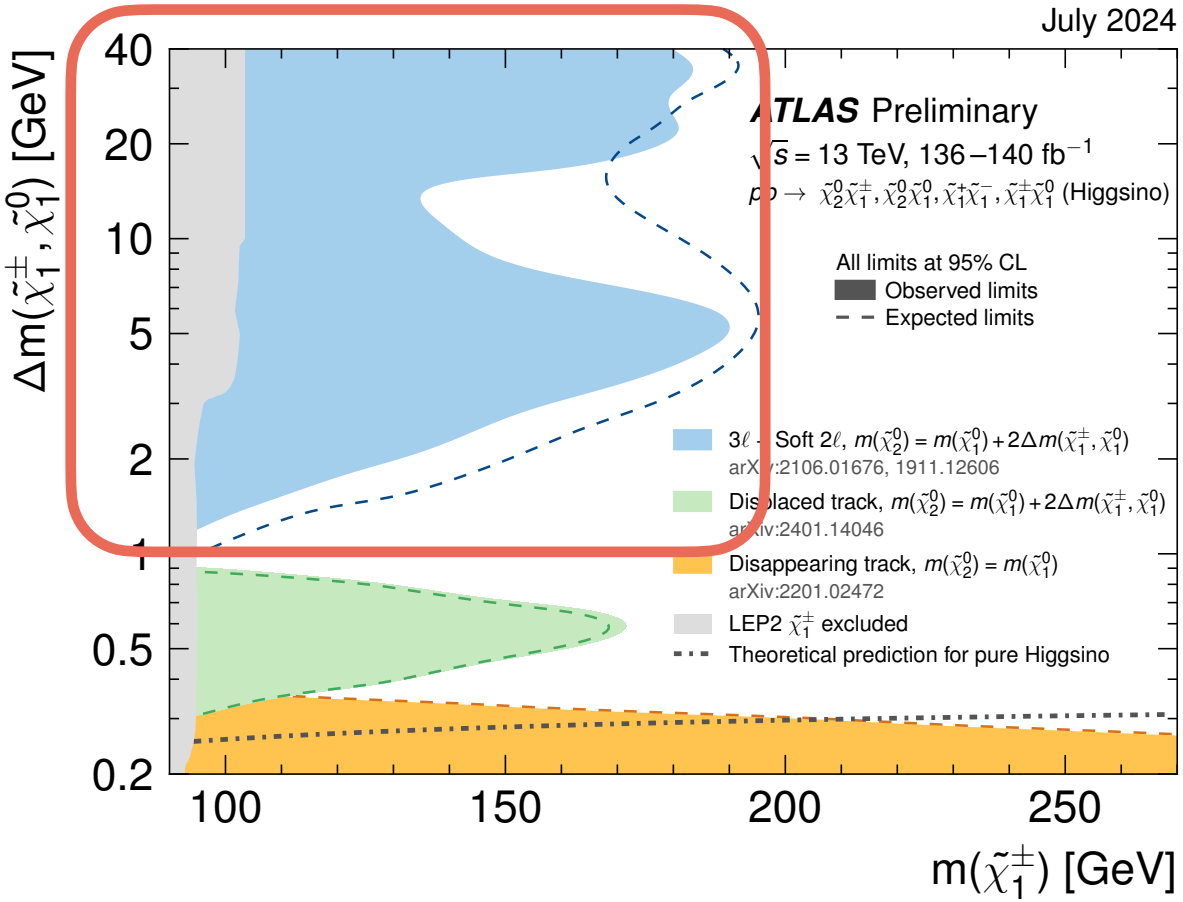
- Challenging signatures at $\Delta m \sim 1$ GeV
- Using ATLAS summary plot from 2024 as canvas
  (could just as well have used one from CMS!)

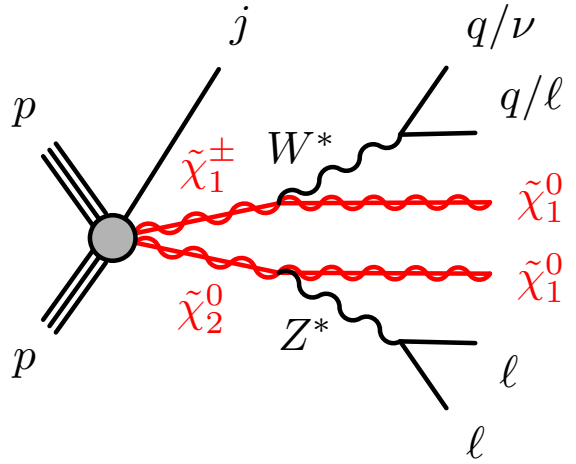


Based on TiKZ figs by I. Neutelings

Compressed electroweakinos

- Challenging signatures at $\Delta m \sim 1$ GeV
- Using ATLAS summary plot from 2024 as canvas
  (could just as well have used one from CMS!)

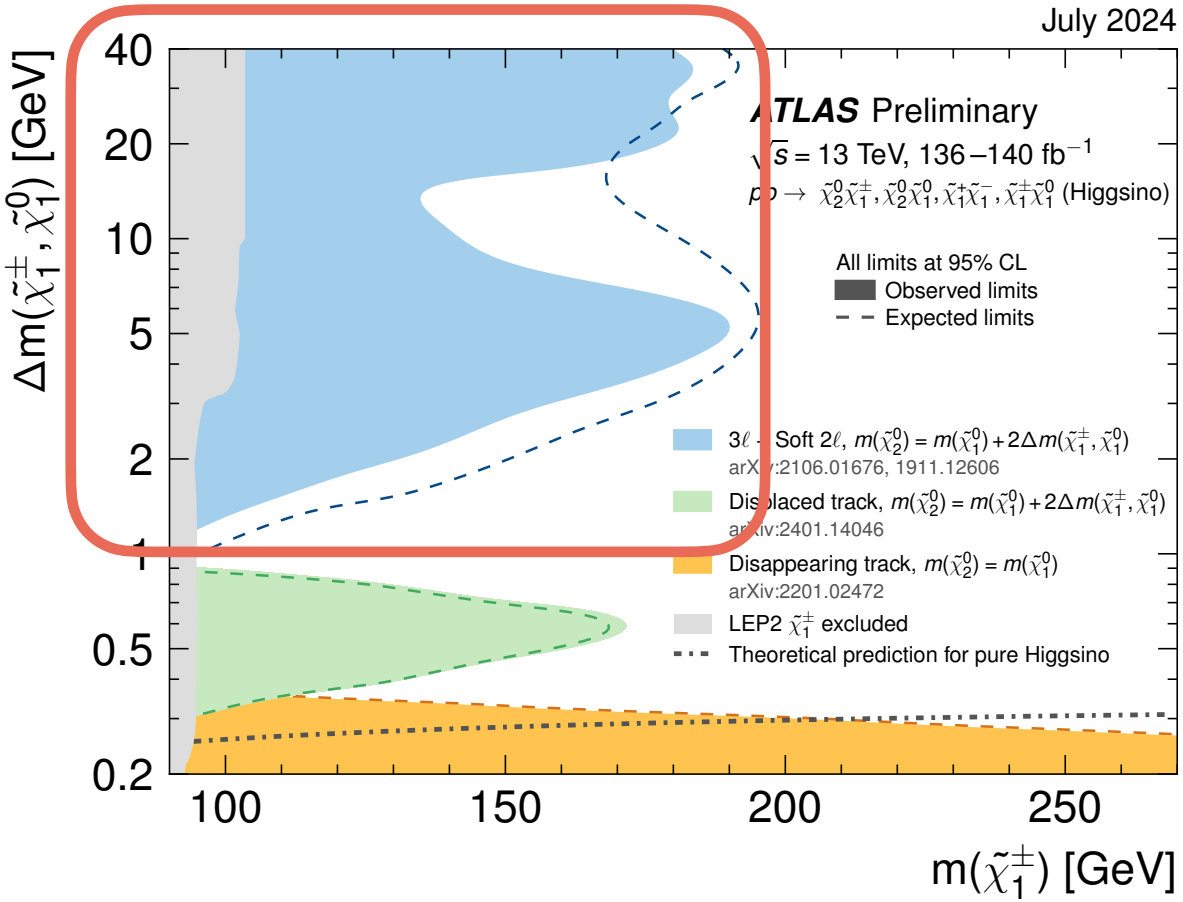


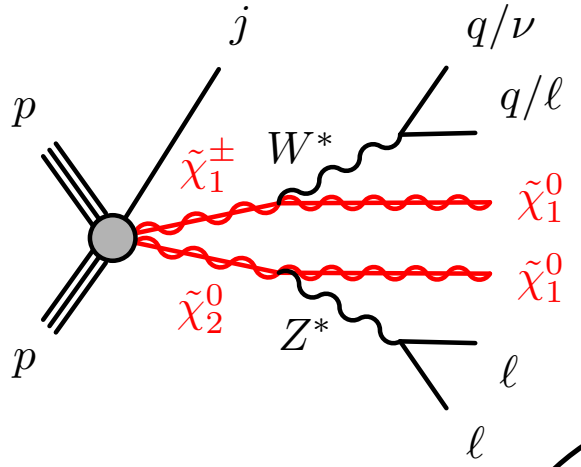


Based on TiKZ figs by I. Neutelings

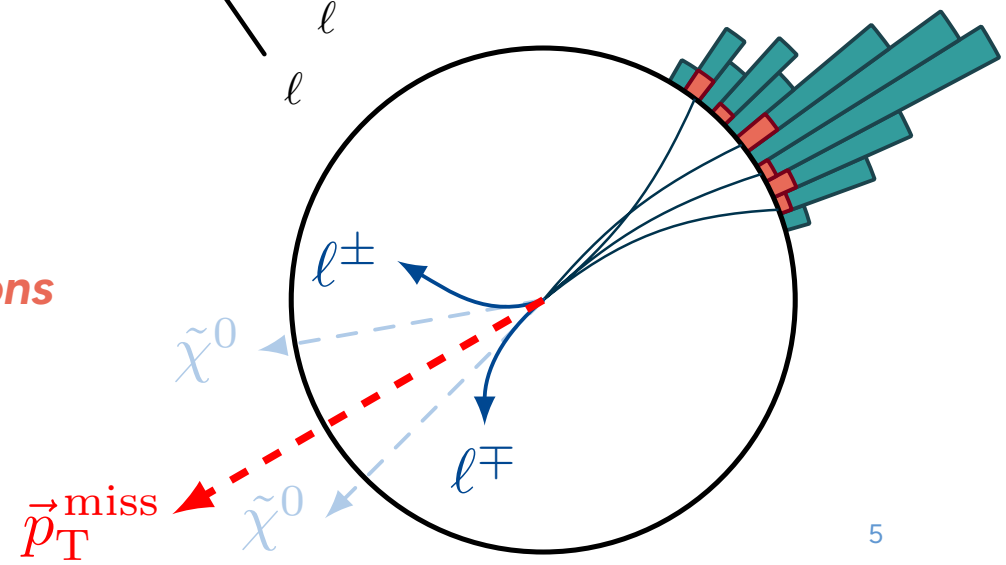
Compressed electroweakinos

- Challenging signatures at $\Delta m \sim 1$ GeV
- Using ATLAS summary plot from 2024 as canvas
  (could just as well have used one from CMS!)





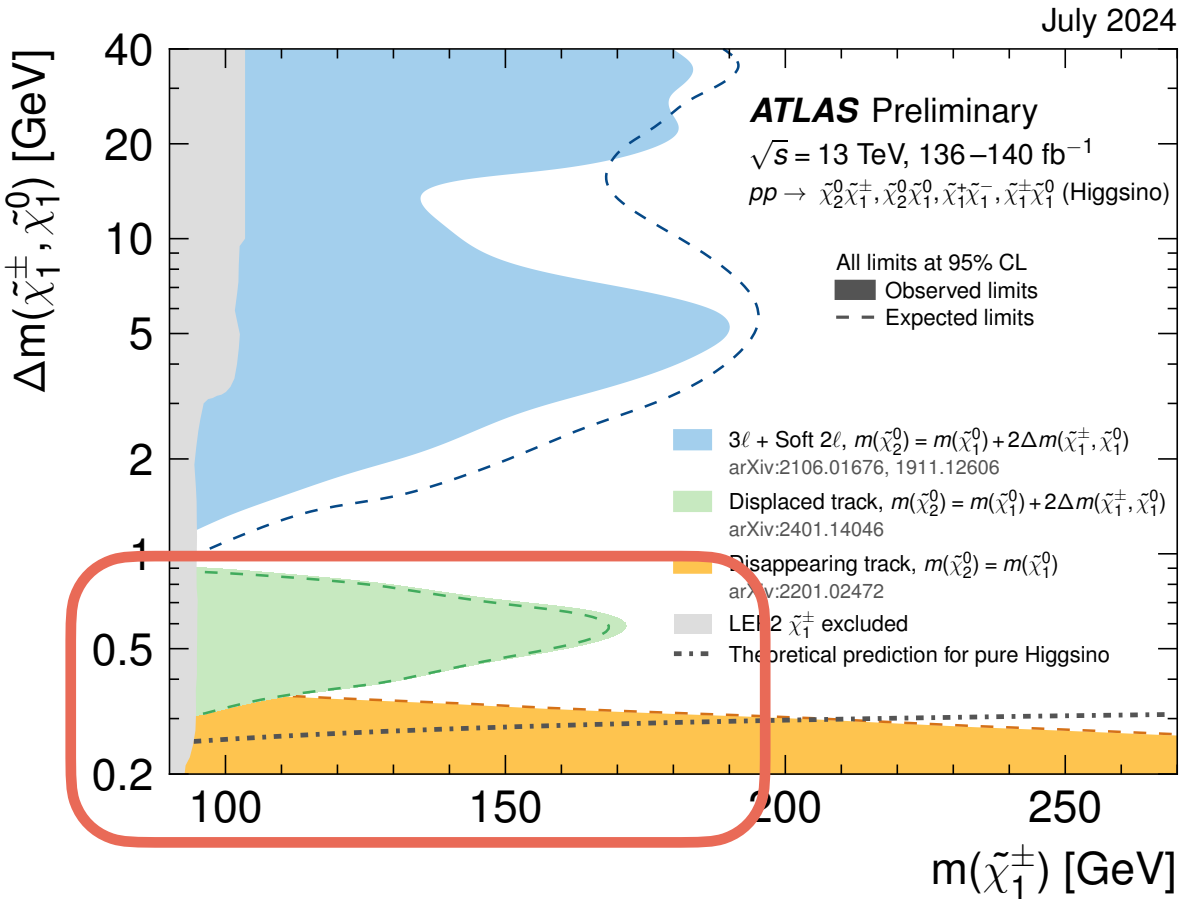
Soft leptons

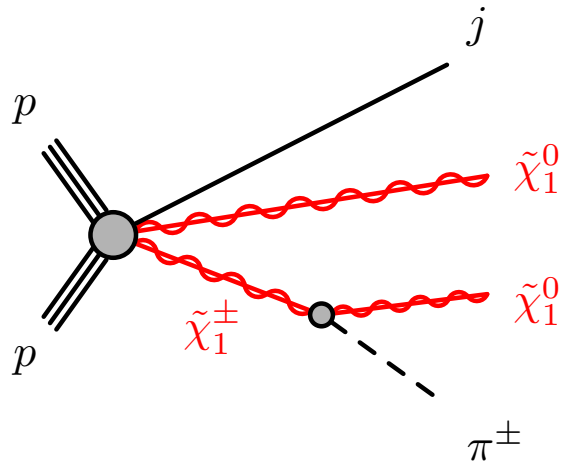


Based on TiKZ figs by I. Neutelings

Compressed electroweakinos

- Challenging signatures at $\Delta m \sim 1$ GeV
- Using ATLAS summary plot from 2024 as canvas
  (could just as well have used one from CMS!)

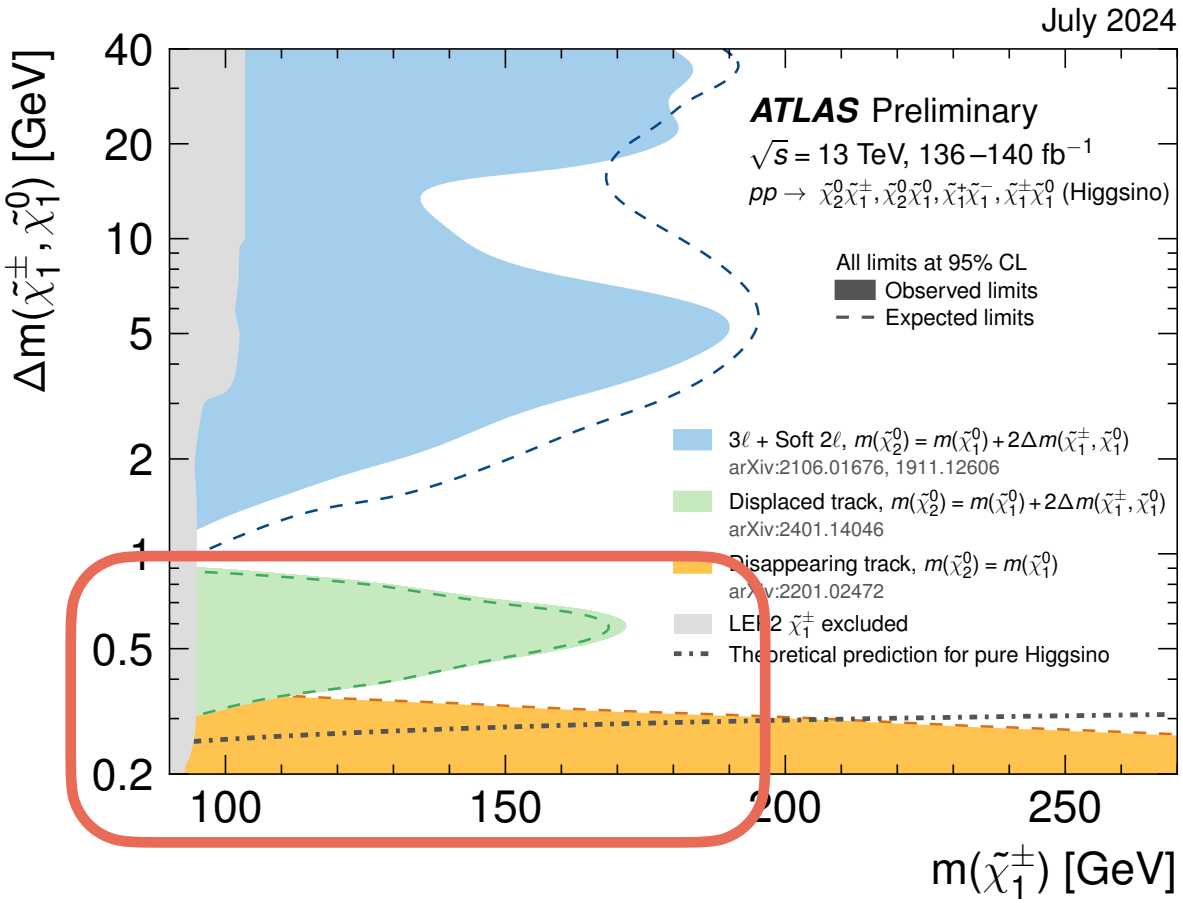


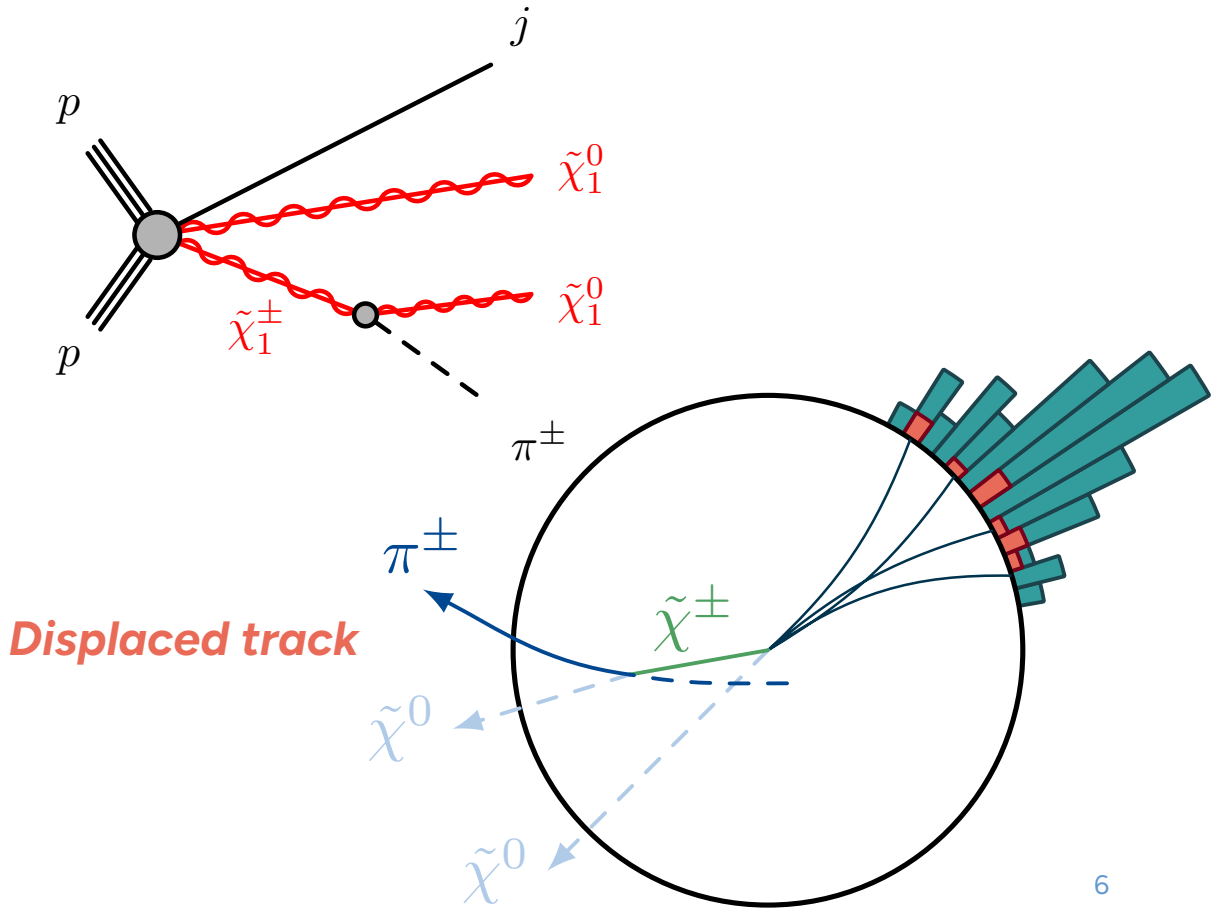


Based on TiKZ figs by I. Neutelings

Compressed electroweakinos

- Challenging signatures at $\Delta m \sim 1$ GeV
- Using ATLAS summary plot from 2024 as canvas
  (could just as well have used one from CMS!)



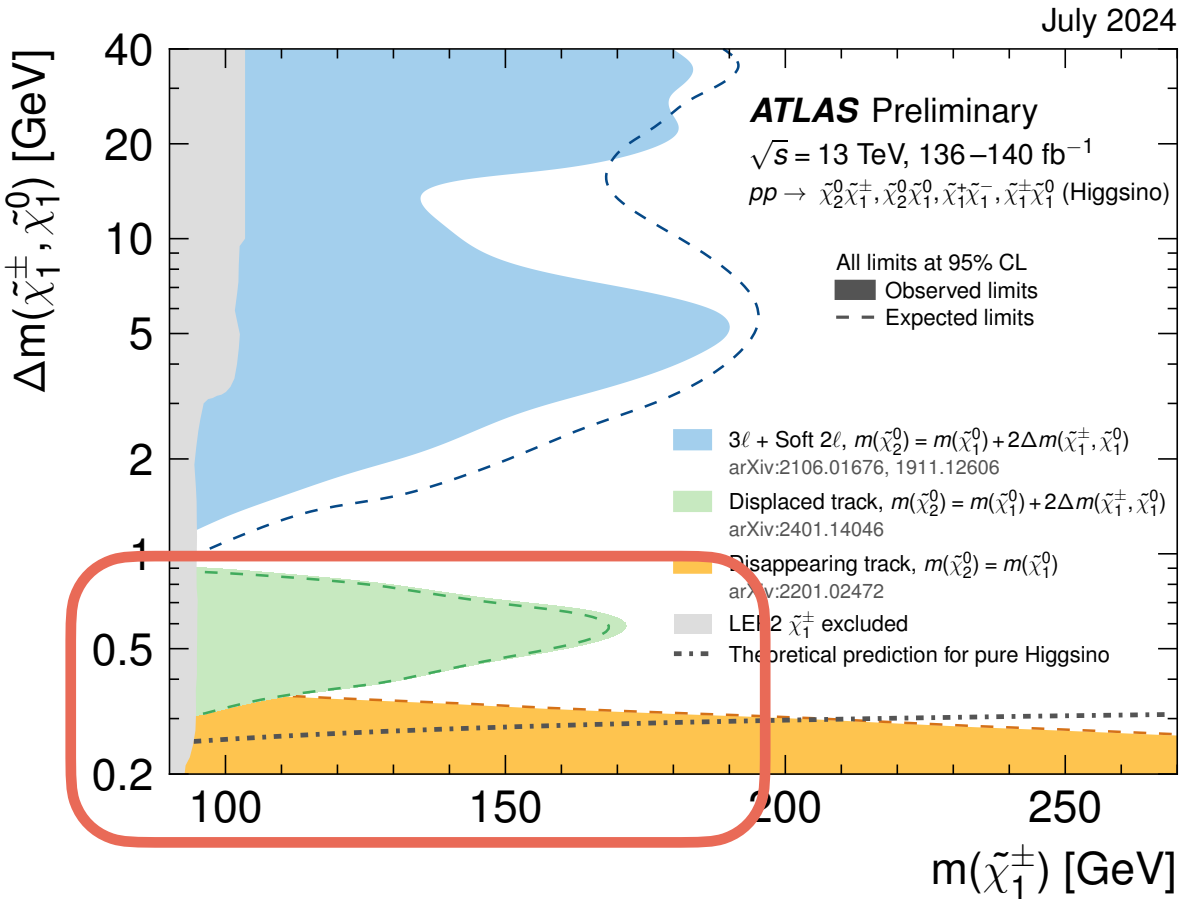


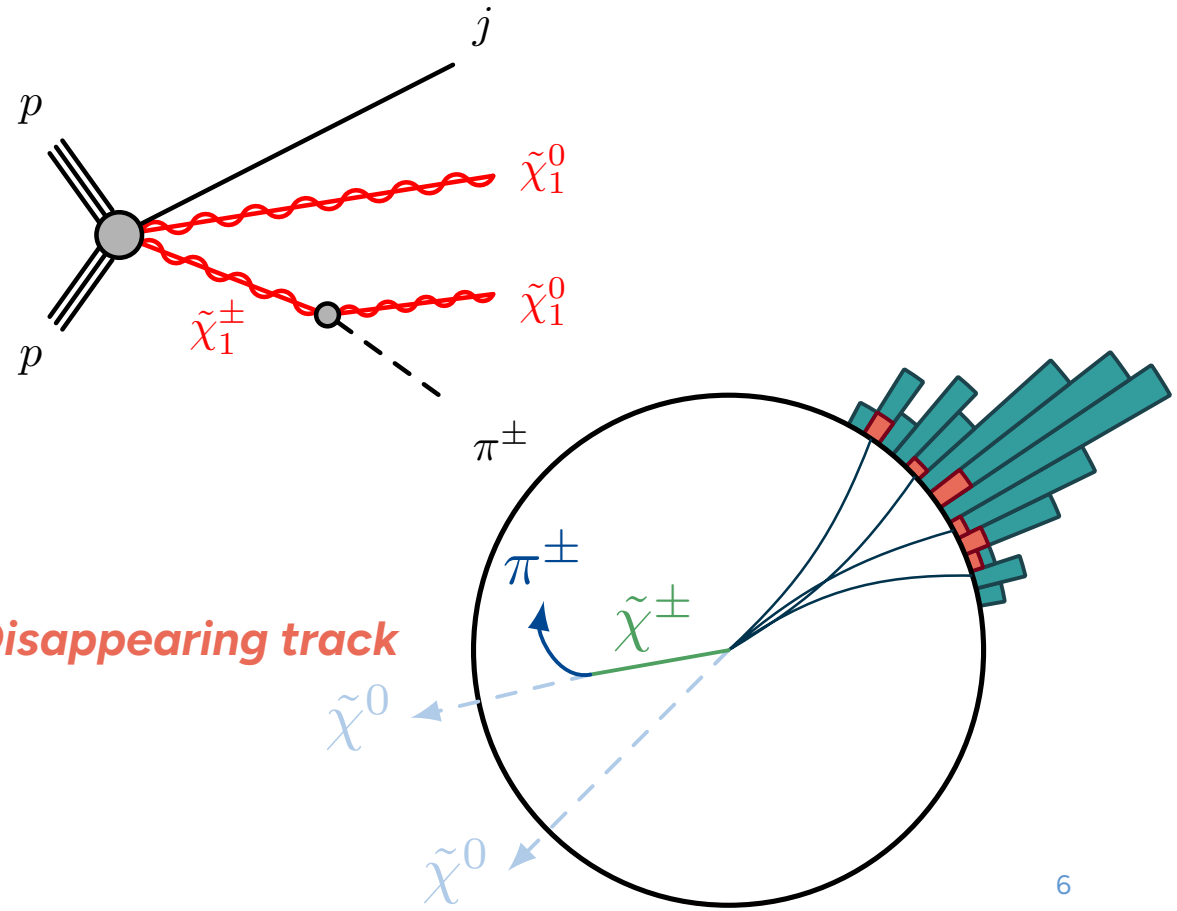
Displaced track

Based on TiKZ figs by I. Neutelings

Compressed electroweakinos

- Challenging signatures at $\Delta m \sim 1$ GeV
- Using ATLAS summary plot from 2024 as canvas
  (could just as well have used one from CMS!)





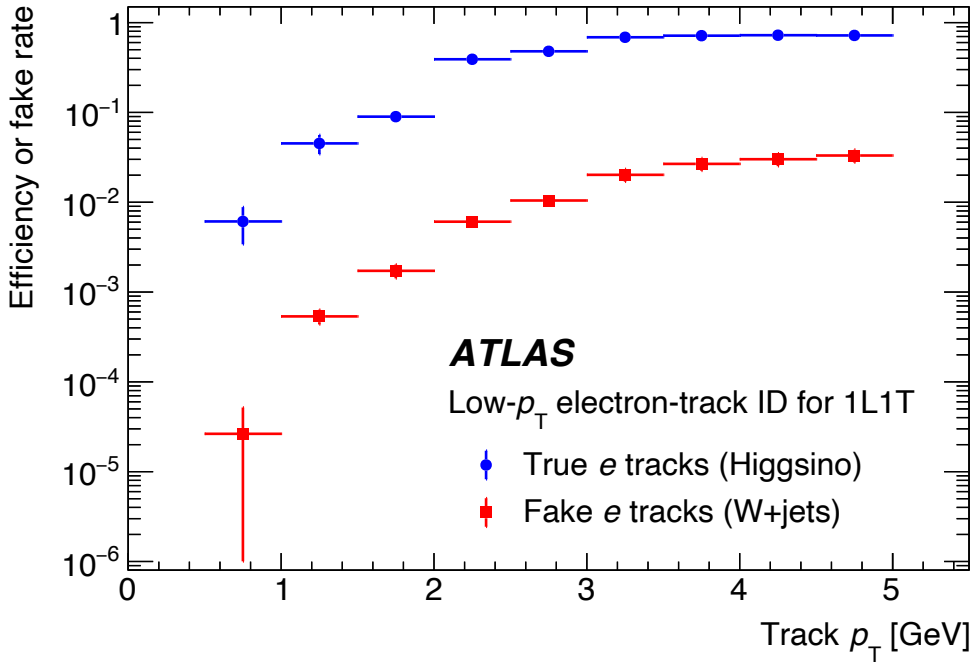
Disappearing track

Based on TiKZ figs by I. Neutelings

Compressed electroweakinos with soft leptons

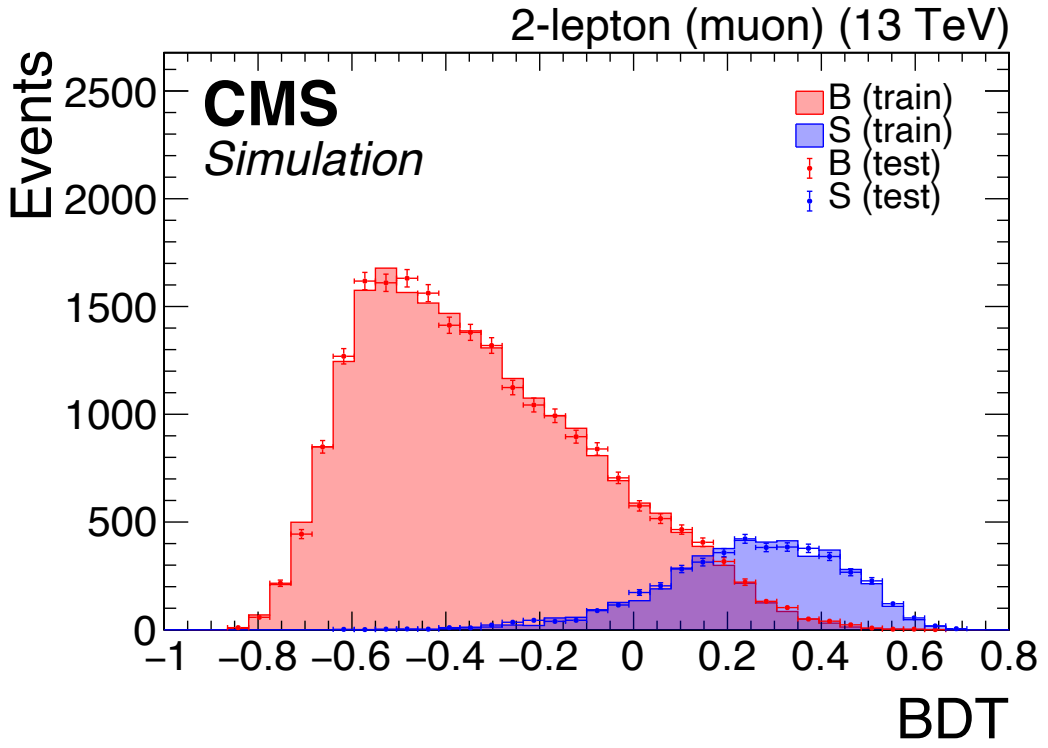
ATLAS - 2511.20042

- Tagger for low-p_{T} leptons: NN using low-level tracking (PID via TRT) and calo info
- Down to $p_{\mathrm{T}}^{e} = 500$ MeV, $p_{\mathrm{T}}^{\mu} = 1$ GeV



CMS - 2511.16394

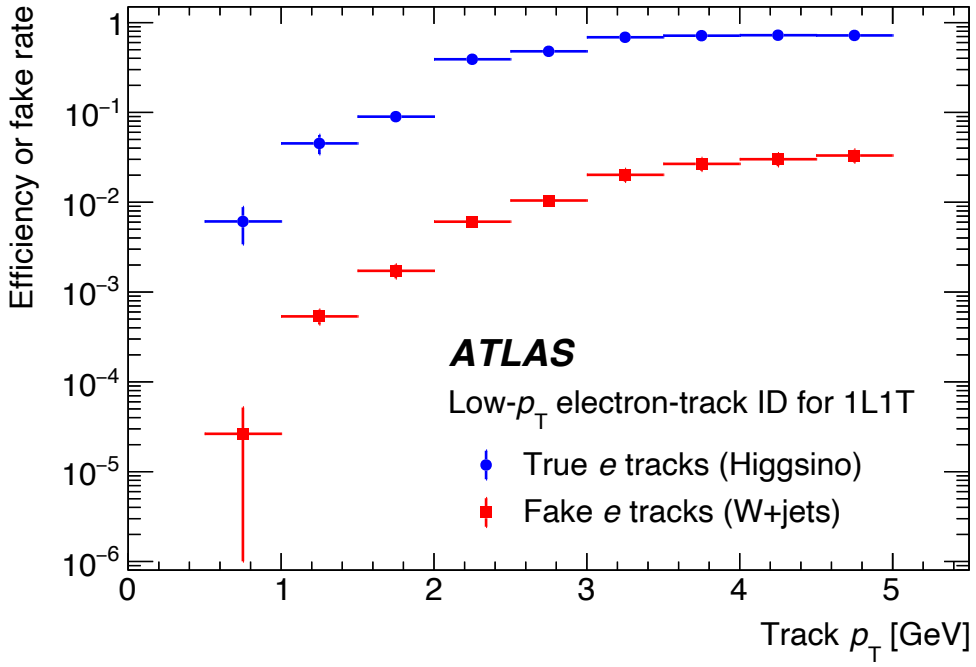
- Event-level BDT using e.g. $\Delta R(t, \ell)$, $\Delta\eta(t, \ell)$, $p_{\mathrm{T}}(\ell)$, $\Delta\phi(t, \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}})$



Compressed electroweakinos with soft leptons

ATLAS - 2511.20042

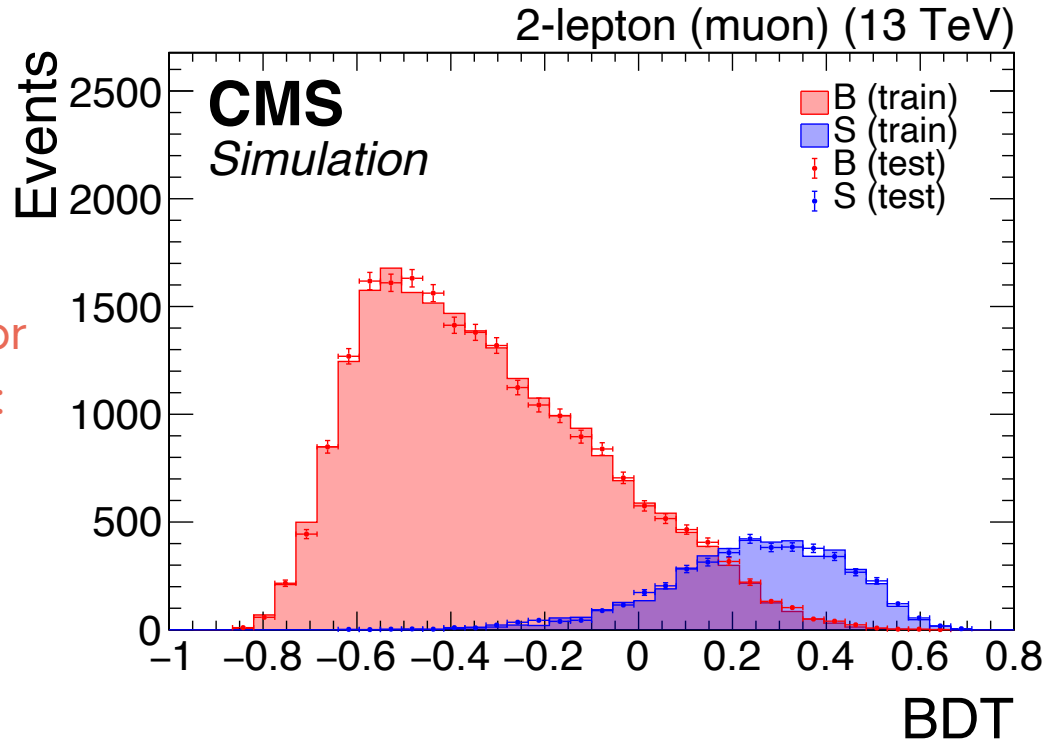
- Tagger for low-p_{T} leptons: NN using low-level tracking (PID via TRT) and calo info
- Down to $p_{\mathrm{T}}^{e} = 500$ MeV, $p_{\mathrm{T}}^{\mu} = 1$ GeV



Backgrounds for low-p_{T} leptons:
- 10% real
- 90% fake

CMS - 2511.16394

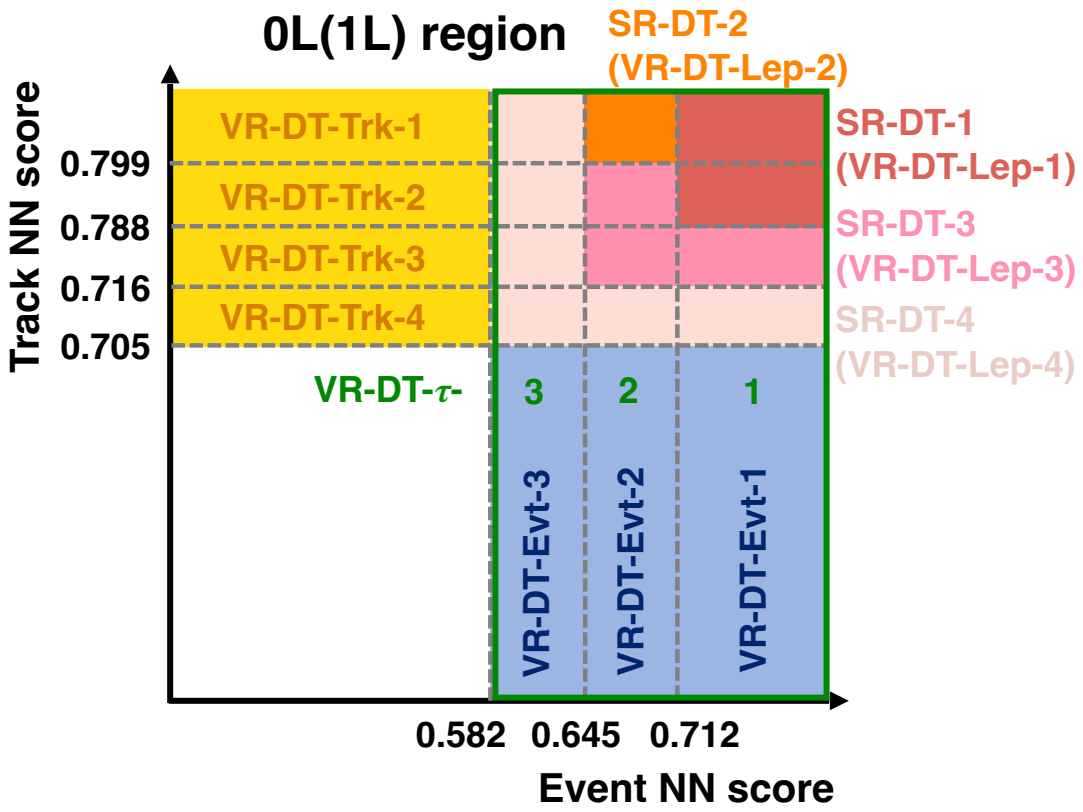
- Event-level BDT using e.g. $\Delta R(t, \ell)$, $\Delta\eta(t, \ell)$, $p_{\mathrm{T}}(\ell)$, $\Delta\phi(t, \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}})$



Compressed electroweakinos with displaced tracks

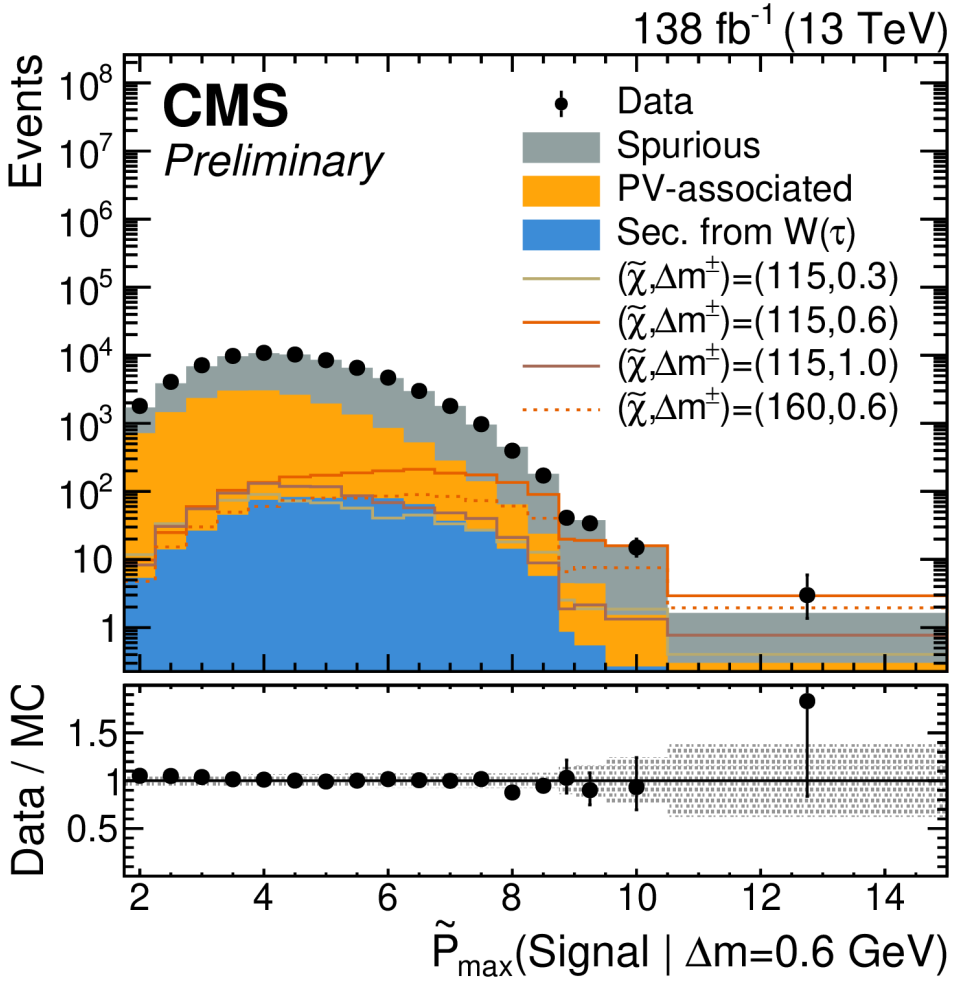
ATLAS - 2511.20042

- SRs defined in 2D of fully connected NNs
  - One for track selection
  - One for event-level selection



CMS - CMS-PAS-SUS-24-012

- NN *parameterized* as function of Δm



Compressed electroweakinos with displaced tracks

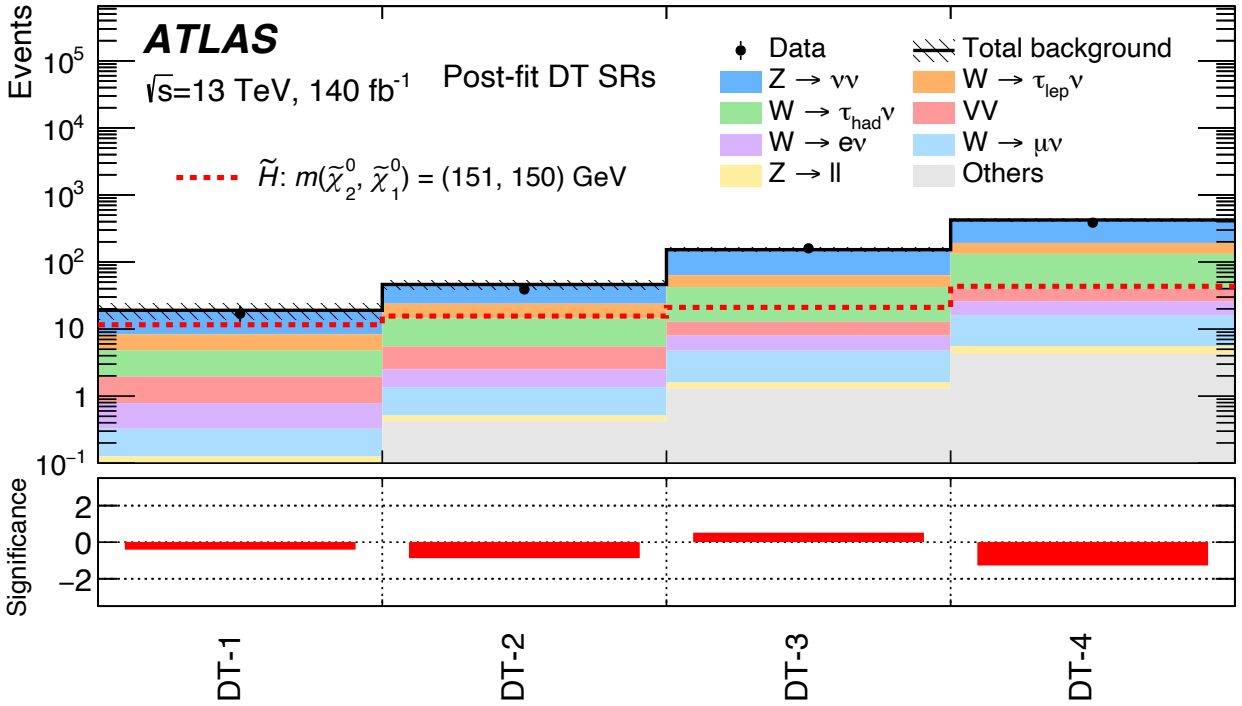
ATLAS - 2511.20042

- Main backgrounds: high-$E_{\mathrm{T}}^{\mathrm{miss}}$ processes, $Z(\nu\nu) + \mathrm{jets}$
- MC normalized in CRs + reweighting for DT
  → expected yields in 4 SRs

Compressed electroweakinos with displaced tracks

ATLAS - 2511.20042

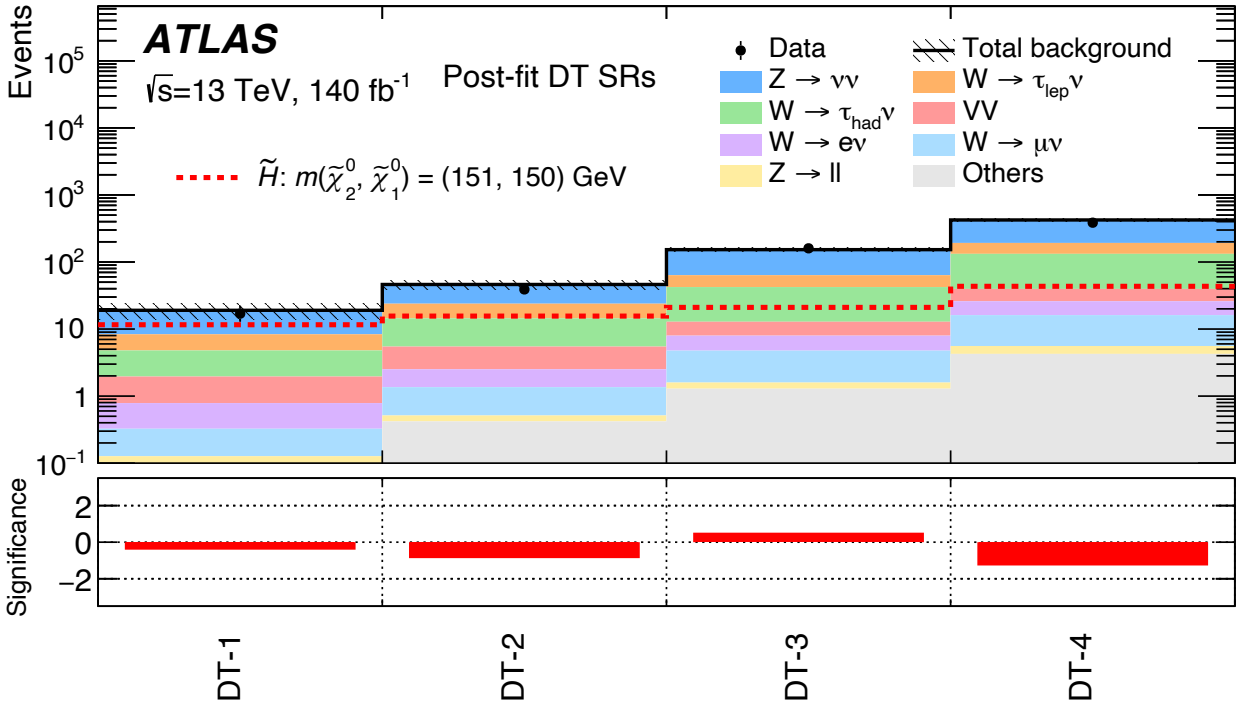
- Main backgrounds: high-$E_{\mathrm{T}}^{\mathrm{miss}}$ processes, $Z(\nu\nu) + \mathrm{jets}$
- MC normalized in CRs + reweighting for DT → expected yields in 4 SRs



Compressed electroweakinos with displaced tracks

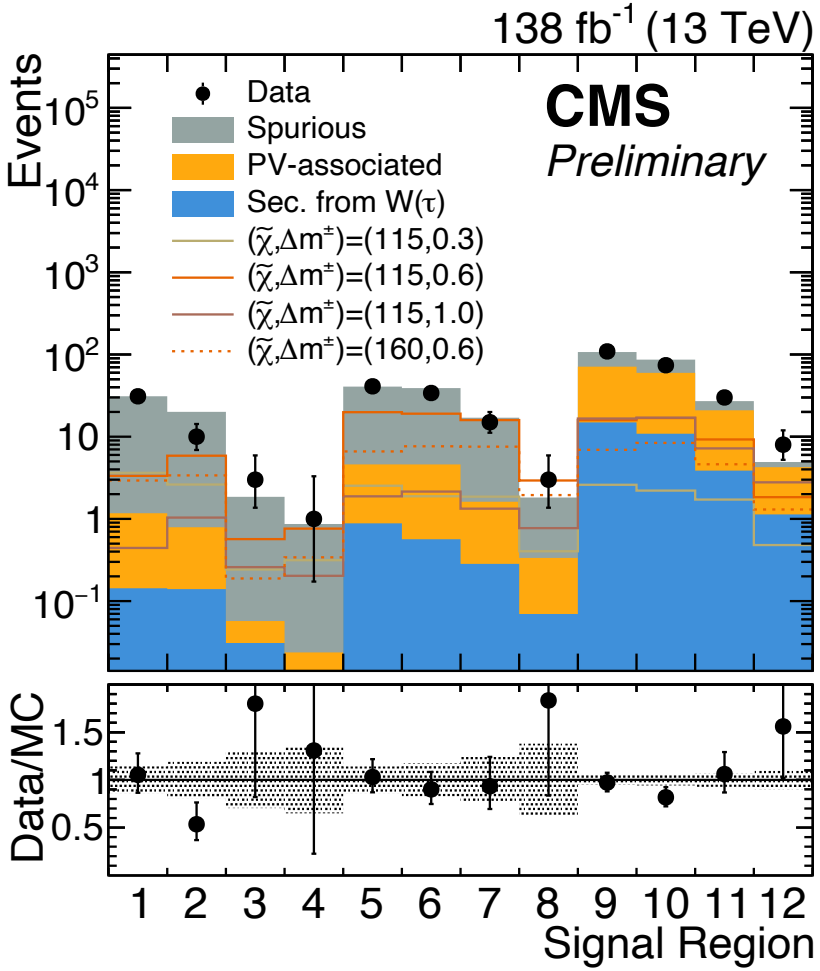
ATLAS - 2511.20042

- Main backgrounds: high-$E_{\mathrm{T}}^{\mathrm{miss}}$ processes, $Z(\nu\nu) + \mathrm{jets}$
- MC normalized in CRs + reweighting for DT → expected yields in 4 SRs



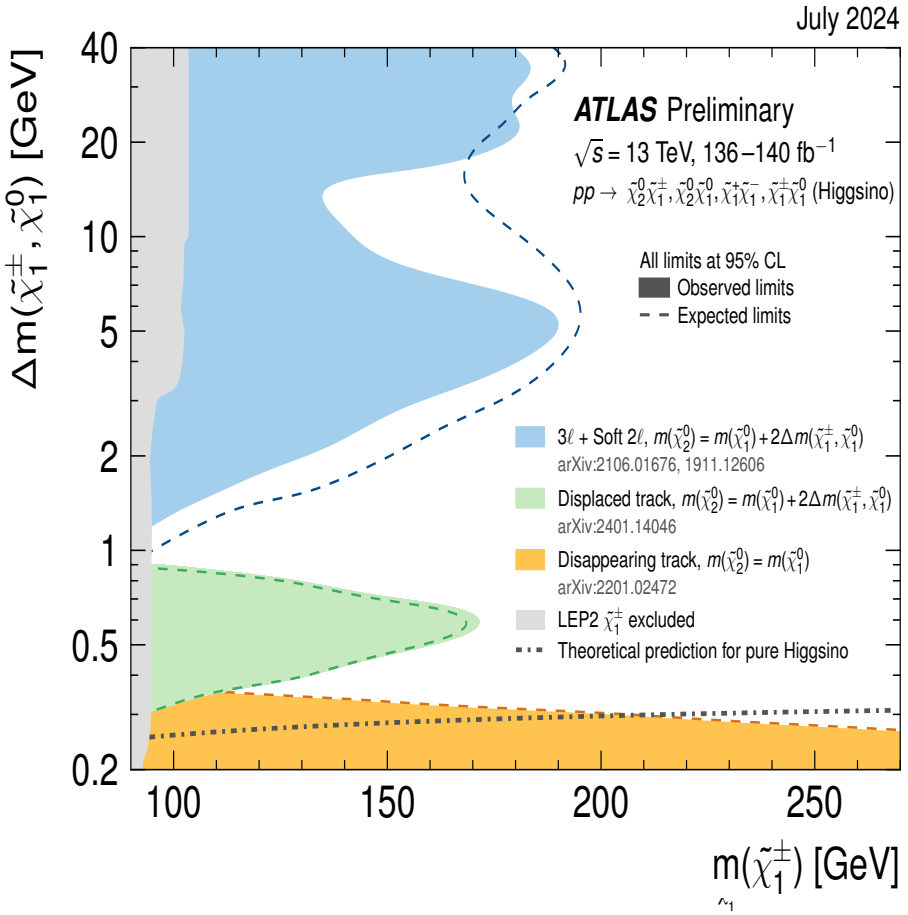
CMS - CMS-PAS-SUS-24-012

- Divided into spurious and PV-assoc
- 12 SRs
- Yields agree with SM-only background expectations



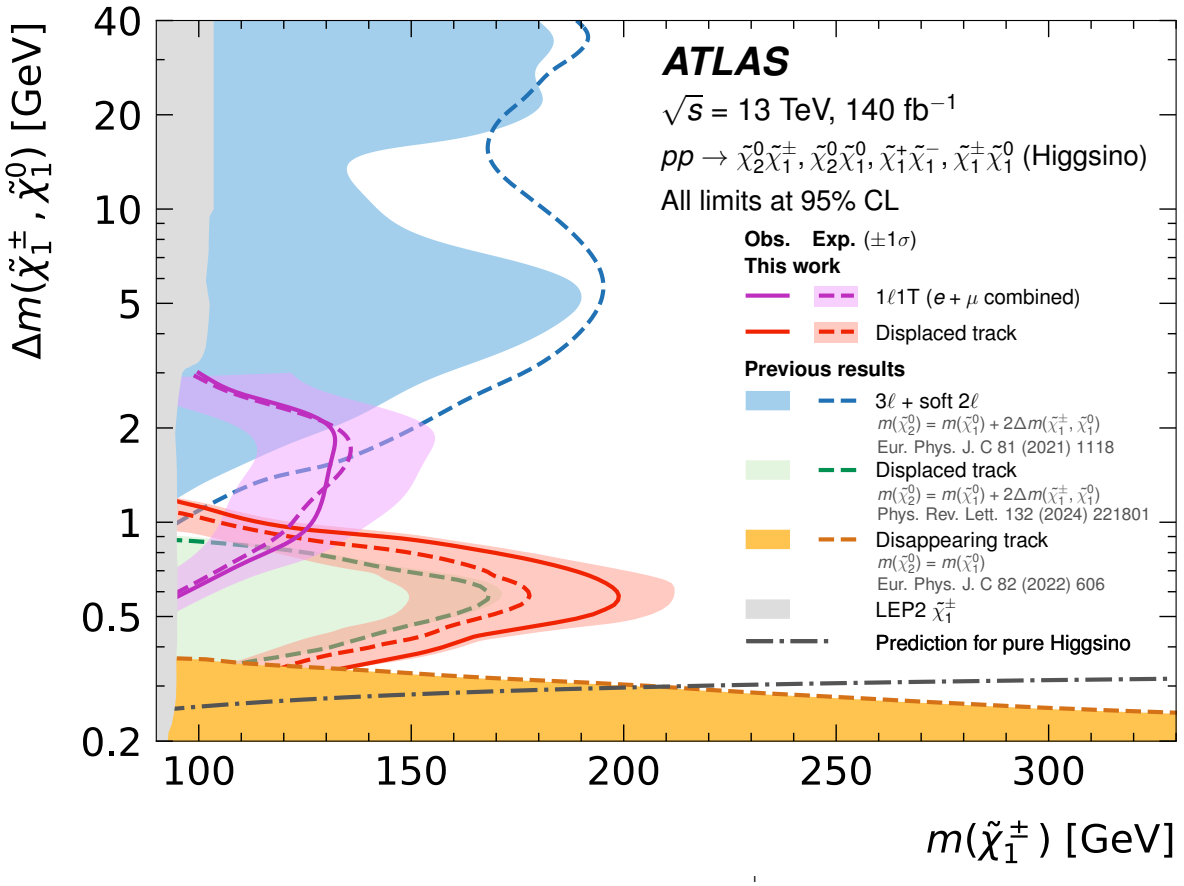
Results for compressed Higgsinos

ATLAS: 2511.20042
CMS: CMS-PAS-EXO-23-017
2511.16394, CMS-PAS-SUS-24-012



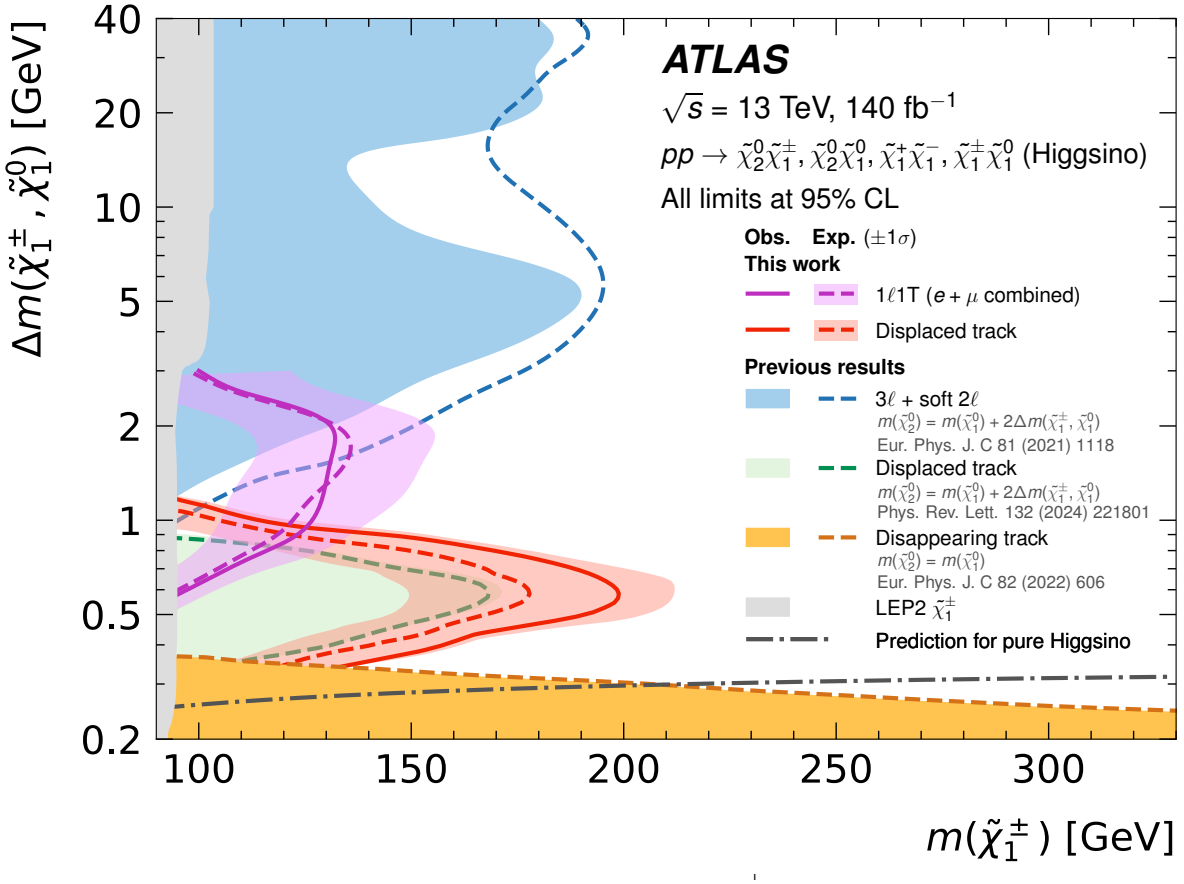
Results for compressed Higgsinos

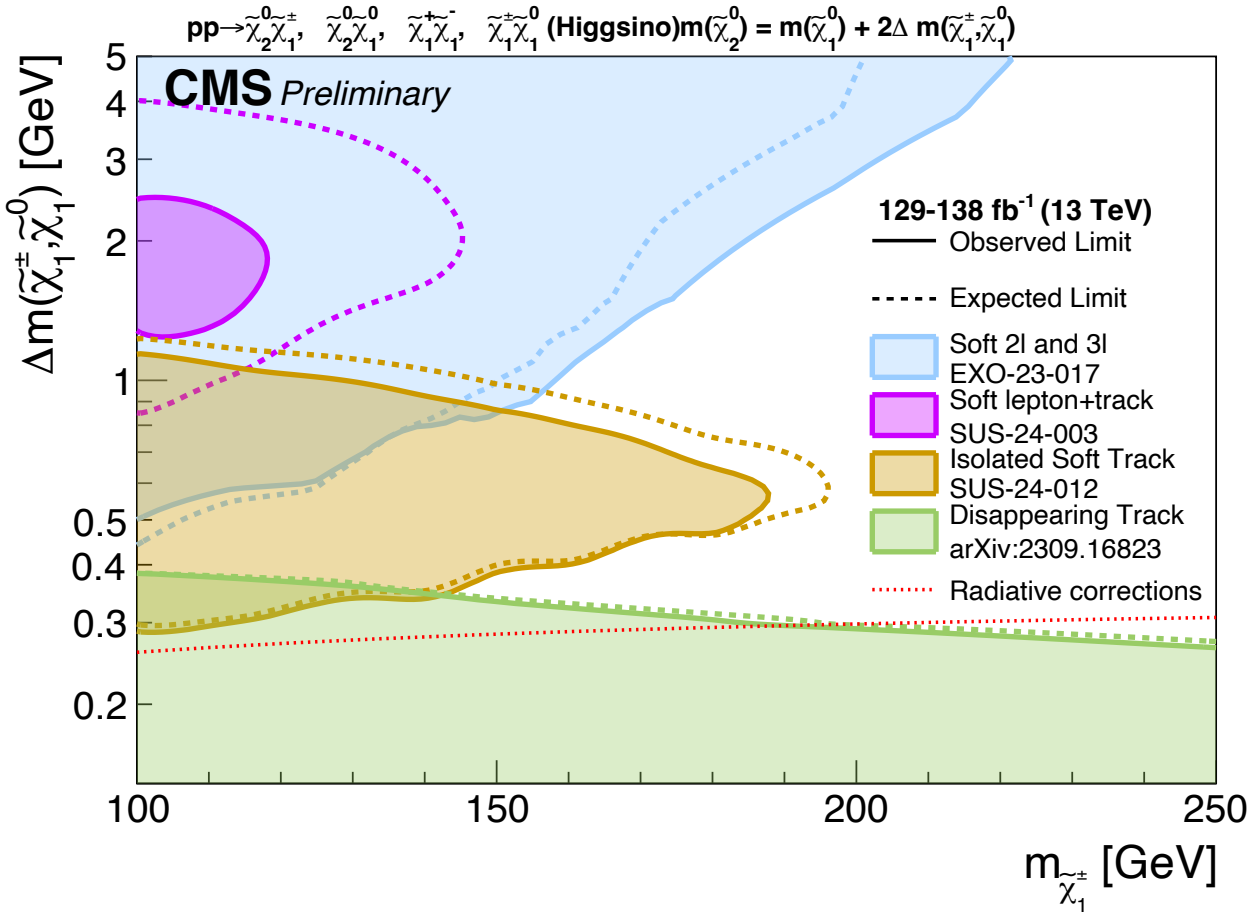
ATLAS: 2511.20042
CMS: CMS-PAS-EXO-23-017
2511.16394, CMS-PAS-SUS-24-012



Results for compressed Higgsinos

ATLAS: 2511.20042
CMS: CMS-PAS-EXO-23-017
2511.16394, CMS-PAS-SUS-24-012



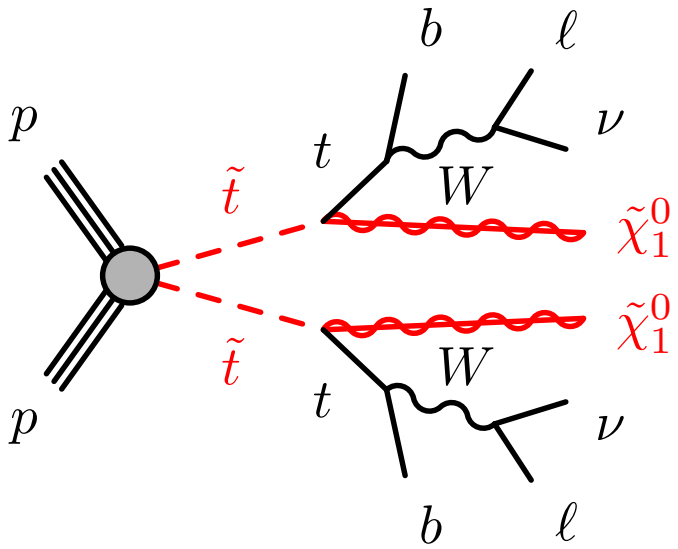


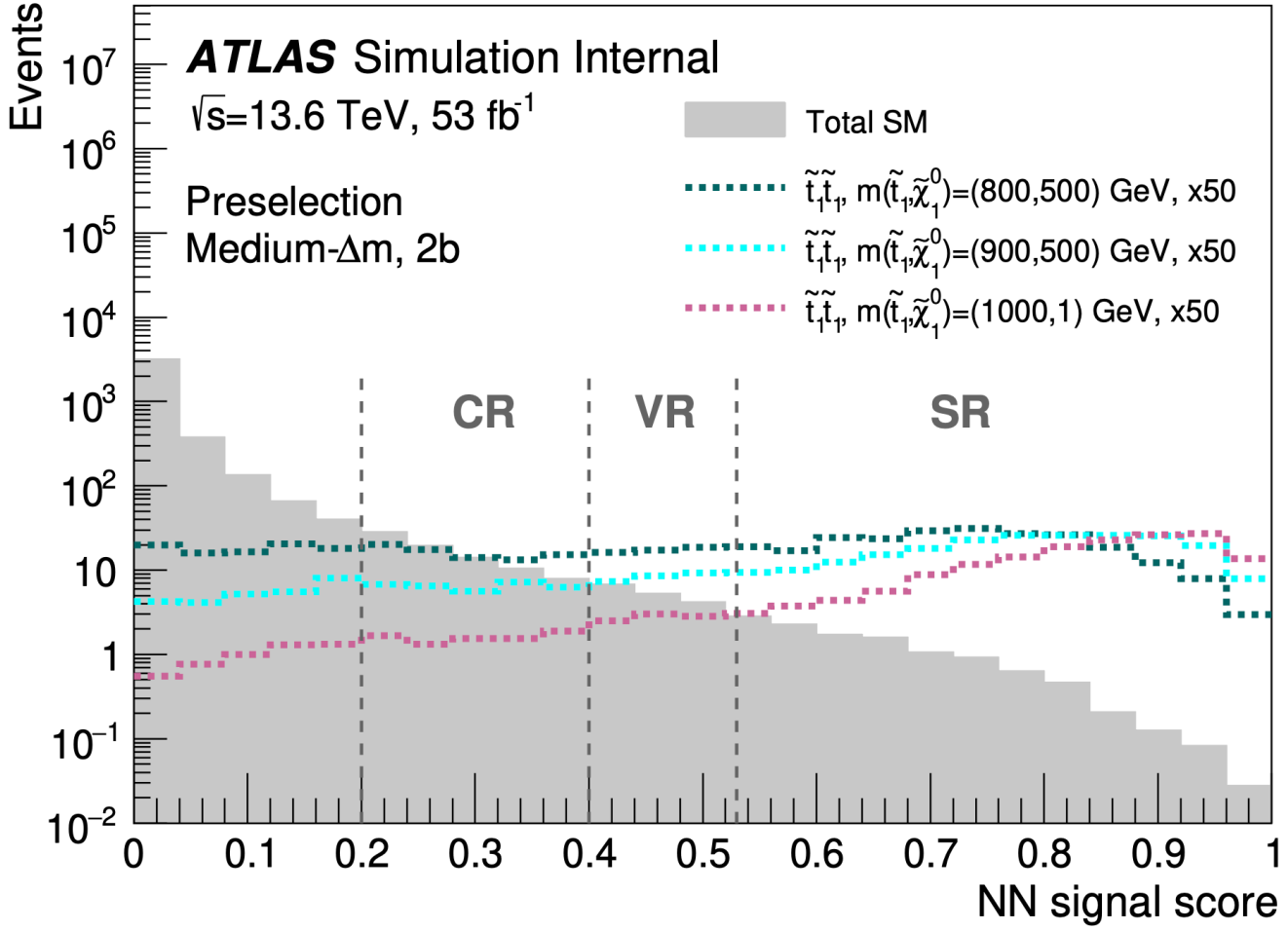
See J. Anders talk tomorrow morning for update on disappearing track result!

Stop-pair search in $2\ell + E_{\mathrm{T}}^{\mathrm{miss}}$ Run 2+3

On arXiv **today**: 2603.16191

- Full Run 2 + partial Run 3 dataset (2022-2023)
- Targets separately different $\Delta m(\tilde{t}, \tilde{\chi}_1^0)$
  - Low: $\Delta m \sim 200 - 300$ GeV
  - Medium: $\Delta m \sim 300 - 500$ GeV
  - High: $\Delta m \gtrsim 600$ GeV
- NNs trained for each, with kinematic variables of jets and leptons as input

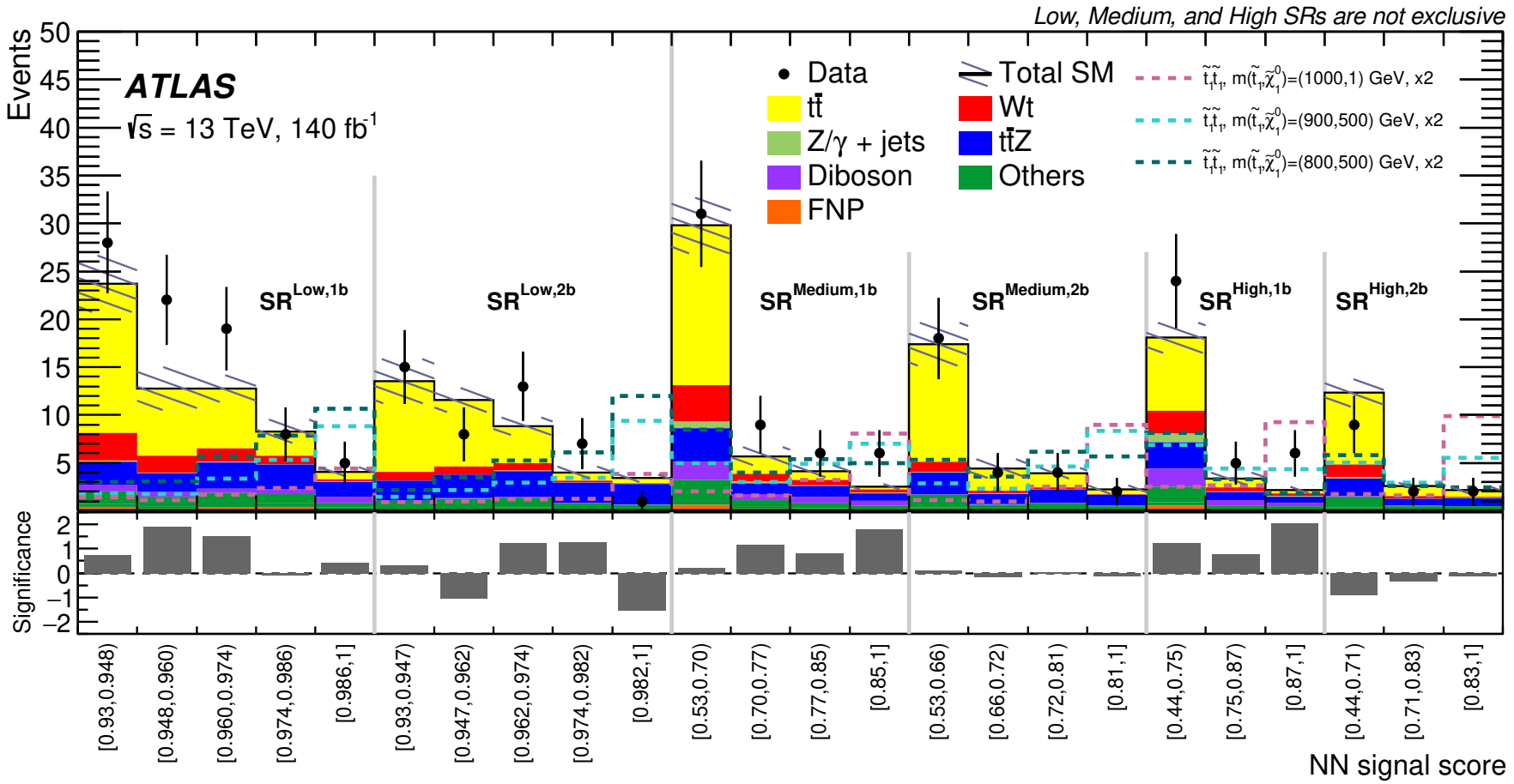




Stop-pair search in $2\ell + E_{\mathrm{T}}^{\mathrm{miss}}$ Run 2+3

On arXiv **today**: 2603.16191

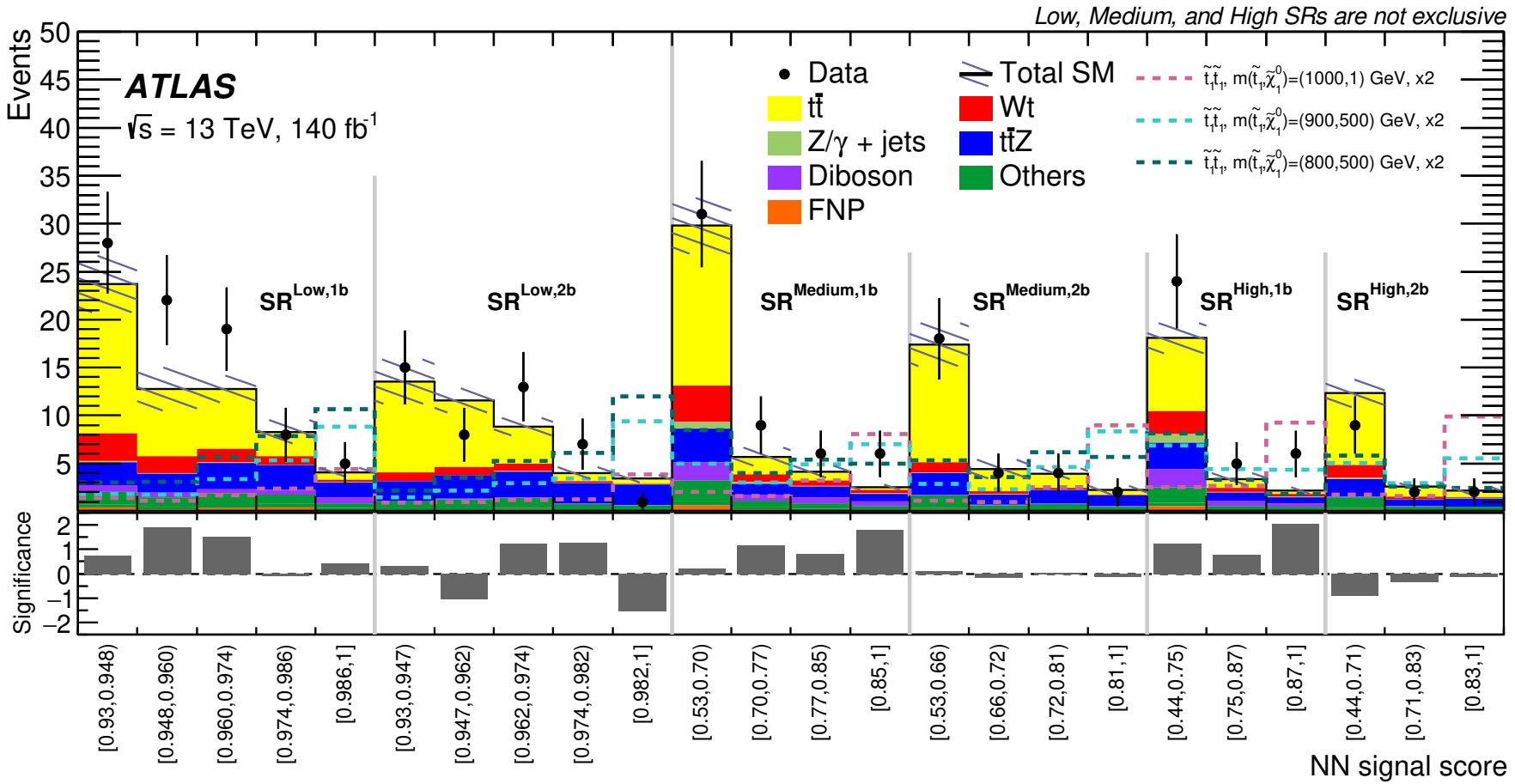
- NN score distributions in all SRs for Run-2 dataset



Stop-pair search in $2\ell + E_{\mathrm{T}}^{\mathrm{miss}}$ Run 2+3

On arXiv **today**: 2603.16191

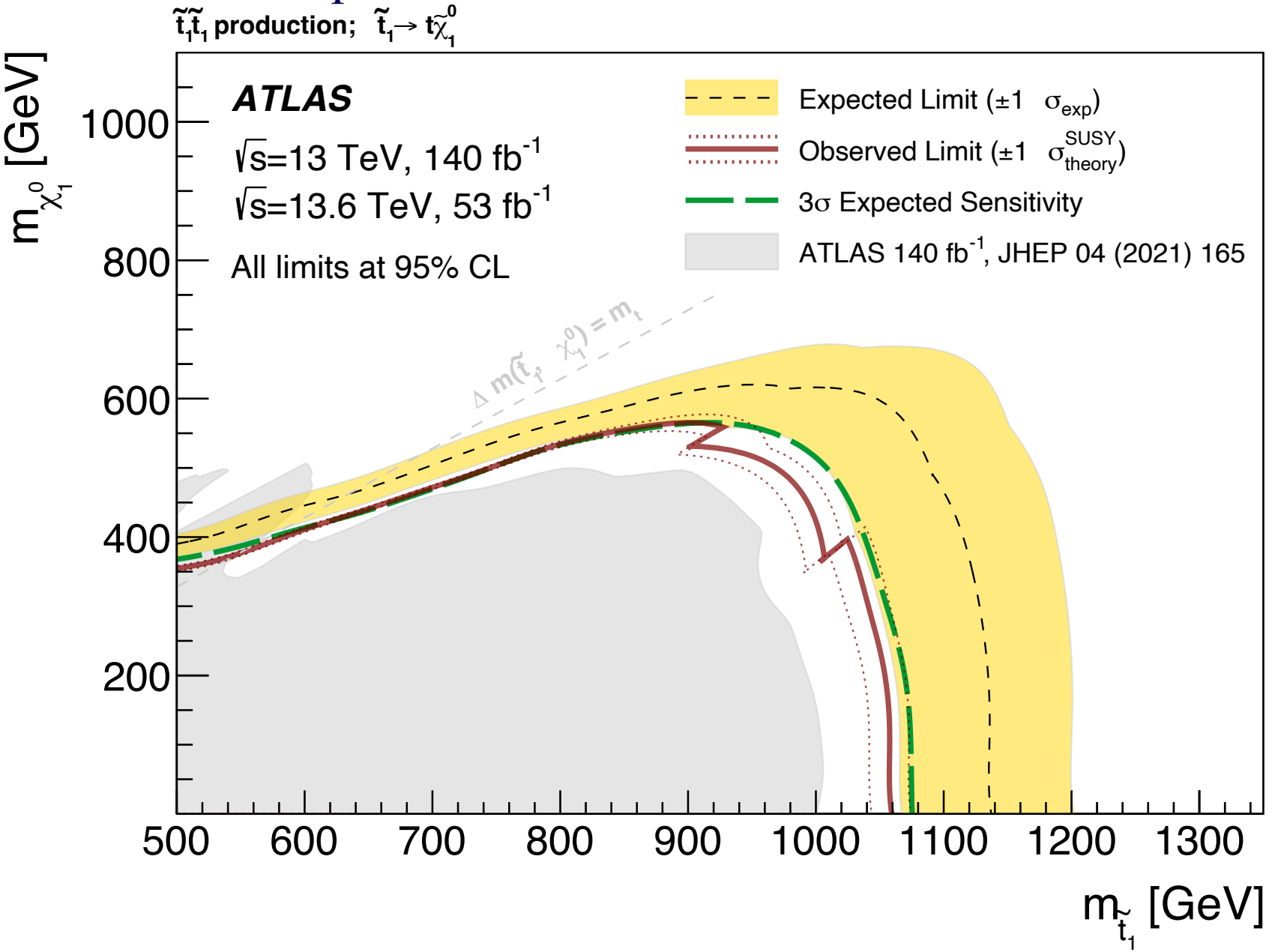
- NN score distributions in all SRs for Run-2 dataset
- Smaller excesses (2σ local) give weaker observed than expected limits



Stop-pair search in $2\ell + E_{\mathrm{T}}^{\mathrm{miss}}$ Run 2+3

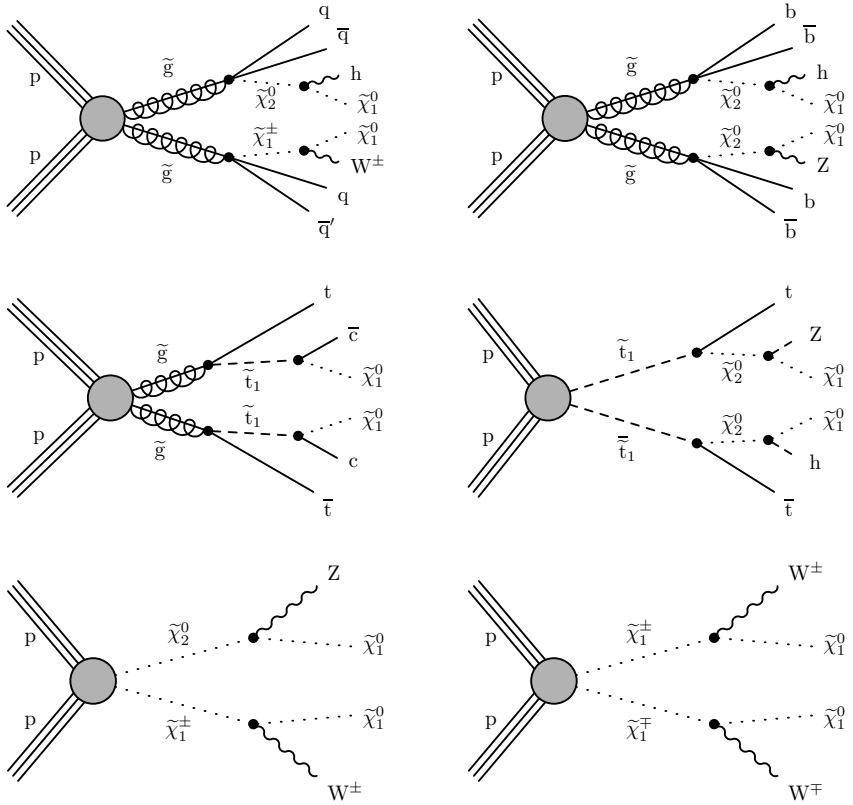
On arXiv **today**: 2603.16191

- NN score distributions in all SRs for Run-2 dataset
- Smaller excesses (2σ local) give weaker observed than expected limits

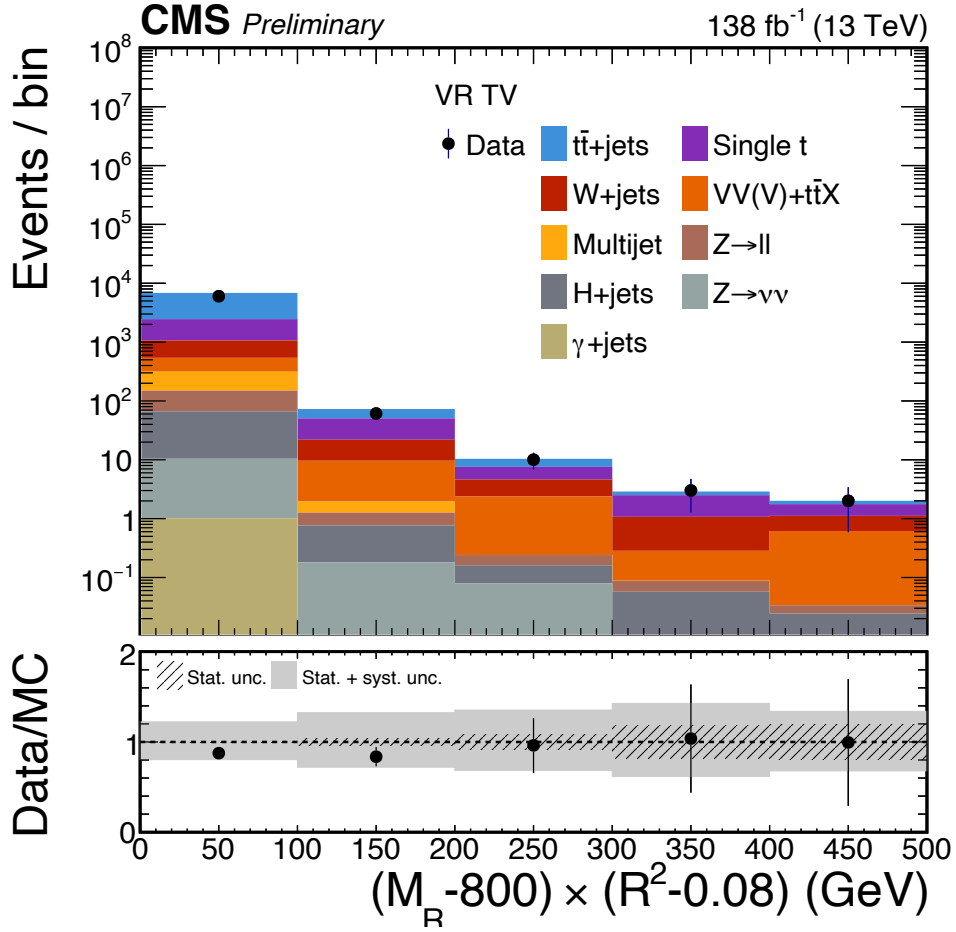


Highly Lorentz-boosted objects

- Search tagging boosted tops, W, Z and Higgs bosons with jet substructure
  - Large anti-k_t jets with $R = 0.8$
- Collimated leptons captured in lepton jets



- The Razor variables exploit decay chain kinematics, M_R and R^2 map event onto dijet topology

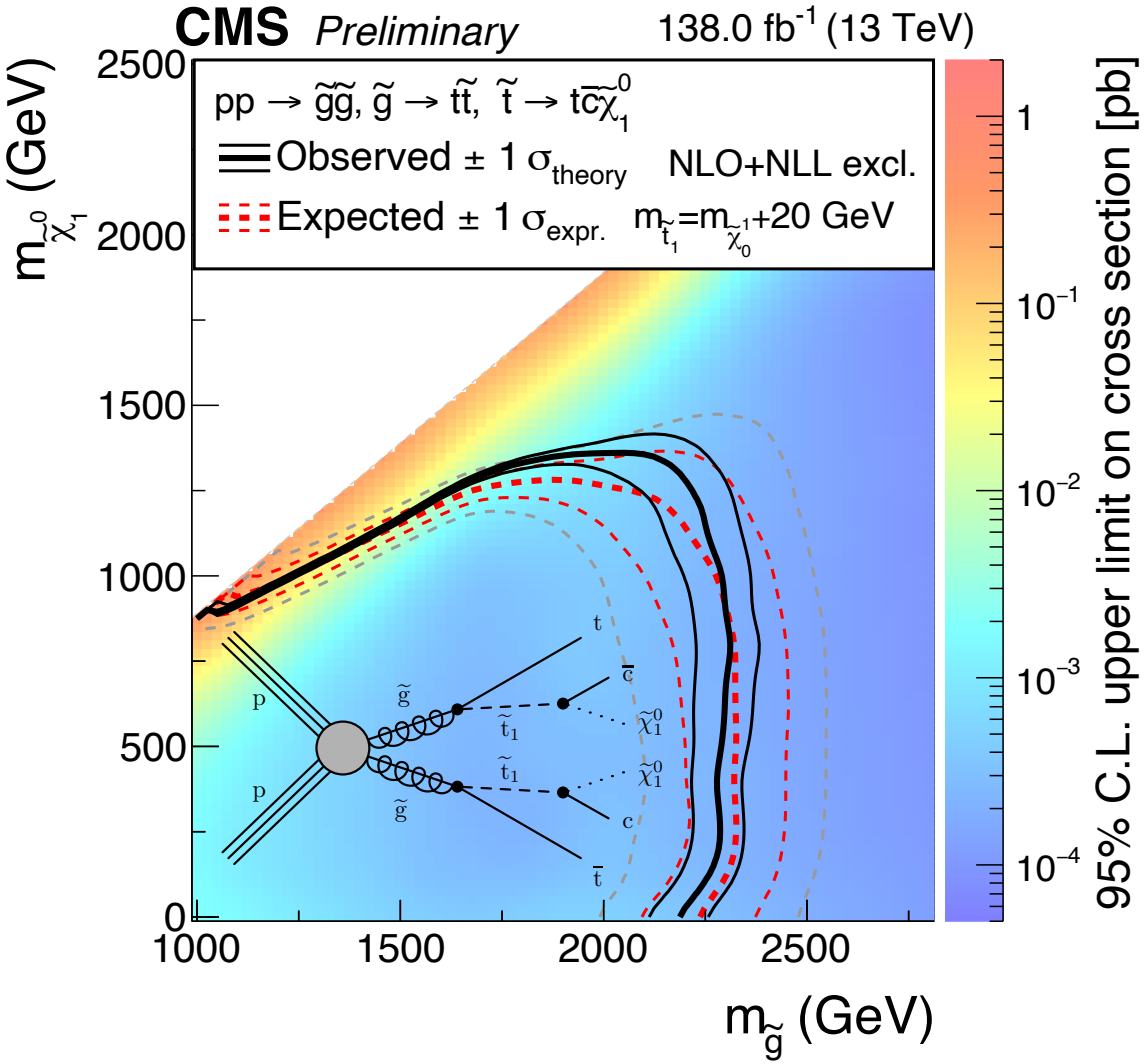


(Paper has 12 figures of this variable)

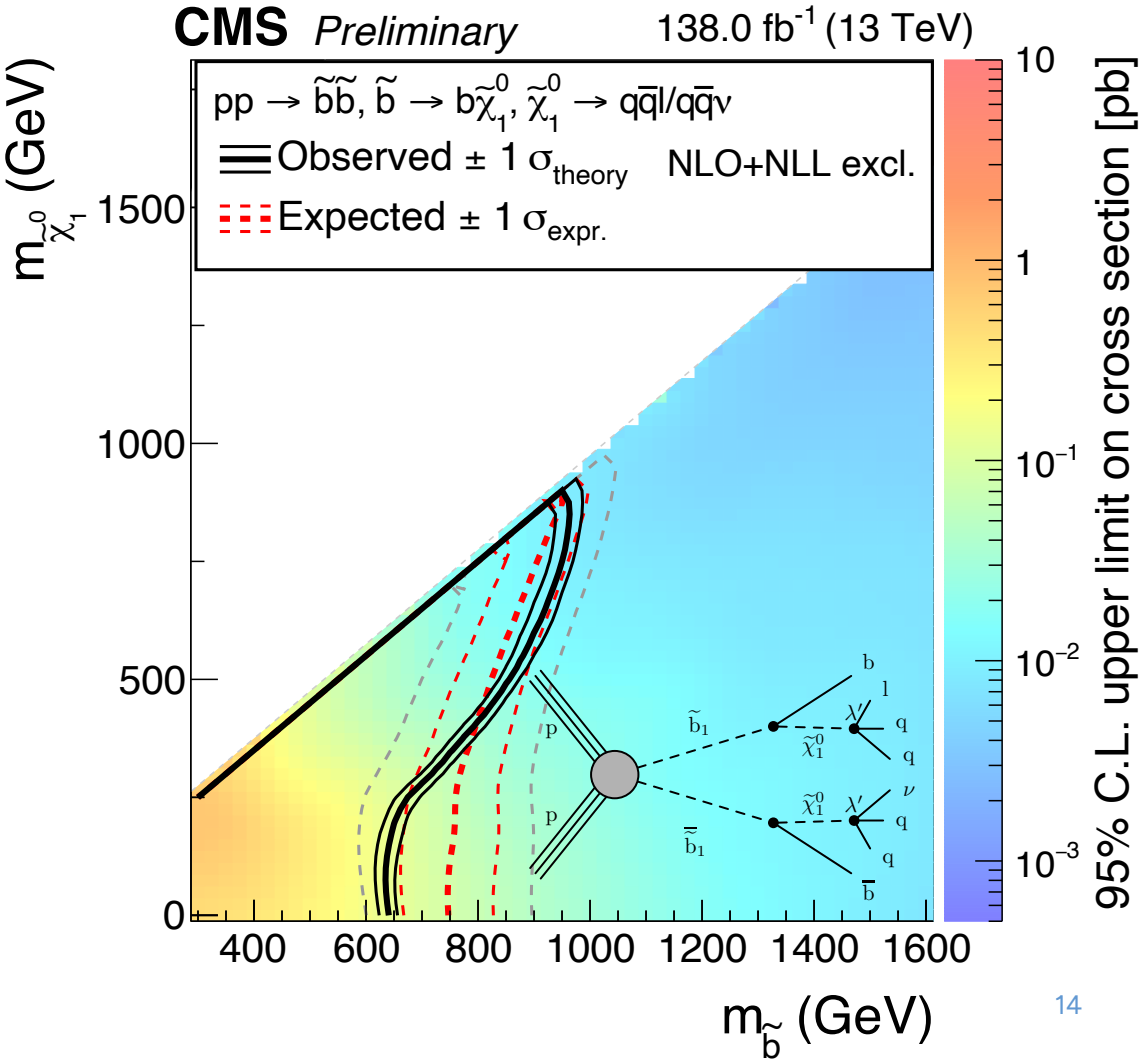
CMS: CMS-PAS-SUS-23-014

Highly Lorentz-boosted objects

Limits on *R*-parity-conserving scenario



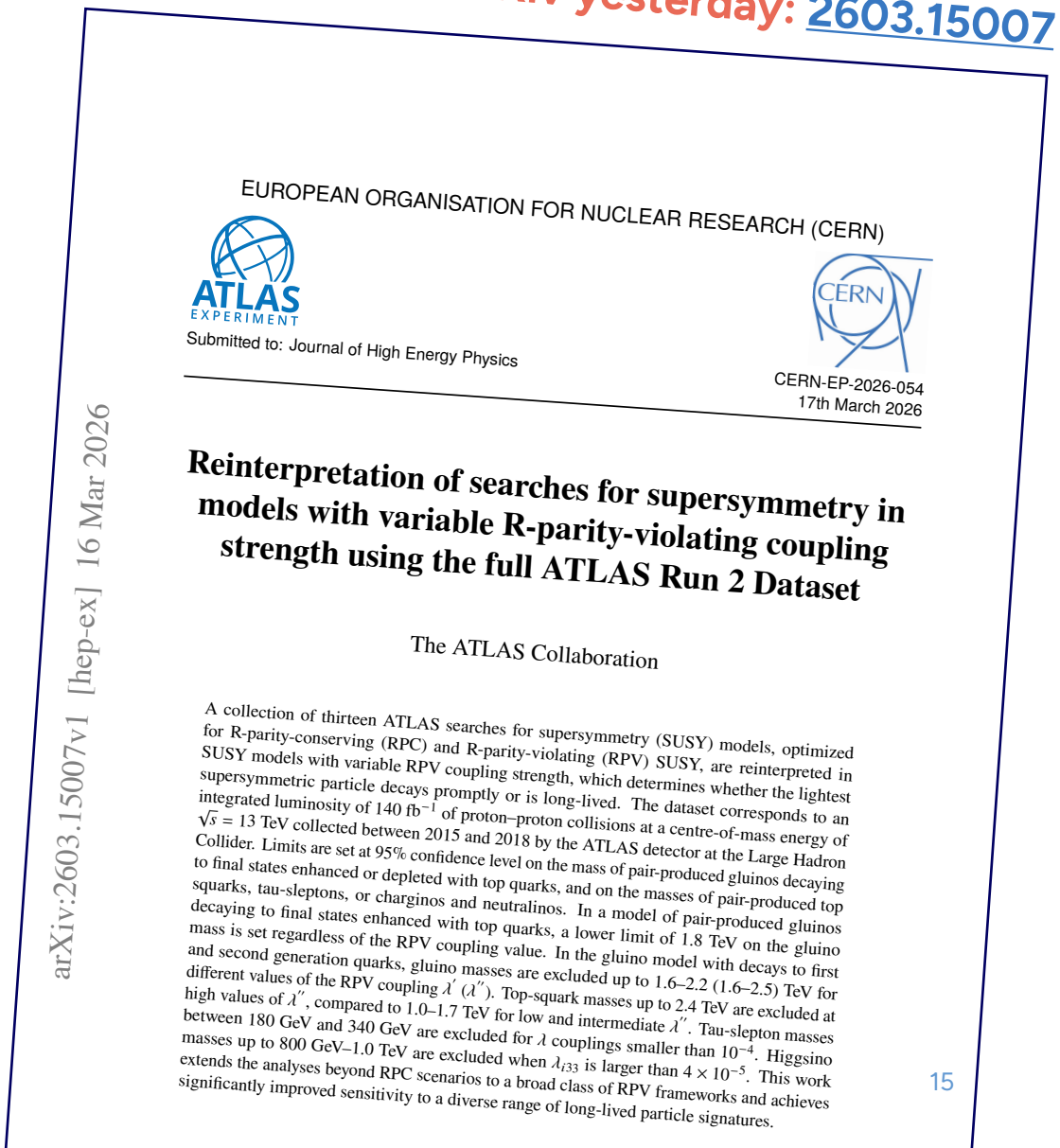
Limits on *R*-parity-violating scenario



Reinterpretation: conservation to violation of *R*-parity

- Comprehensive program targeting signatures of
  - Promptly decaying SUSY particles
  - Long-lived SUSY particles
- What if the new particles are somewhere in between?
  - Effort to ***determine sensitivity to very small R-parity-violating couplings***
  - Do we have a gap?

On arXiv yesterday: 2603.15007



EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Submitted to: Journal of High Energy Physics

CERN-EP-2026-054
17th March 2026

Reinterpretation of searches for supersymmetry in models with variable R-parity-violating coupling strength using the full ATLAS Run 2 Dataset

The ATLAS Collaboration

A collection of thirteen ATLAS searches for supersymmetry (SUSY) models, optimized for R-parity-conserving (RPC) and R-parity-violating (RPV) SUSY, are reinterpreted in SUSY models with variable RPV coupling strength, which determines whether the lightest supersymmetric particle decays promptly or is long-lived. The dataset corresponds to an integrated luminosity of 140 fb^{-1} of proton–proton collisions at a centre-of-mass energy of $\sqrt{s}$ = 13 TeV collected between 2015 and 2018 by the ATLAS detector at the Large Hadron Collider. Limits are set at 95% confidence level on the mass of pair-produced gluinos decaying to final states enhanced or depleted with top quarks, and on the masses of pair-produced top squarks, tau-sleptons, or charginos and neutralinos. In a model of pair-produced gluinos decaying to final states enhanced with top quarks, a lower limit of 1.8 TeV on the gluino mass is set regardless of the RPV coupling value. In the gluino model with decays to first and second generation quarks, gluino masses are excluded up to 1.6–2.2 (1.6–2.5) TeV for different values of the RPV coupling λ'' (λ'). Top-squark masses up to 2.4 TeV are excluded at high values of λ'', compared to 1.0–1.7 TeV for low and intermediate λ''. Tau-slepton masses between 180 GeV and 340 GeV are excluded for λ couplings smaller than 10^{-4}. Higgsino masses up to 800 GeV–1.0 TeV are excluded when λ_{i33} is larger than 4×10^{-5}. This work extends the analyses beyond RPC scenarios to a broad class of RPV frameworks and achieves significantly improved sensitivity to a diverse range of long-lived particle signatures.

Reinterpretation: conservation to violation of *R*-parity

- Comprehensive program targeting signatures of
  - Promptly decaying SUSY particles
  - Long-lived SUSY particles
- What if the new particles are somewhere in between?
  - Effort to ***determine sensitivity to very small R-parity-violating couplings***
  - Do we have a gap?
- Reinterpreted ***13 searches*** optimized for prompt or displaced decay signatures
- Extra care to account for additional uncertainties, e.g. jet-energy scale for particles from displaced decays

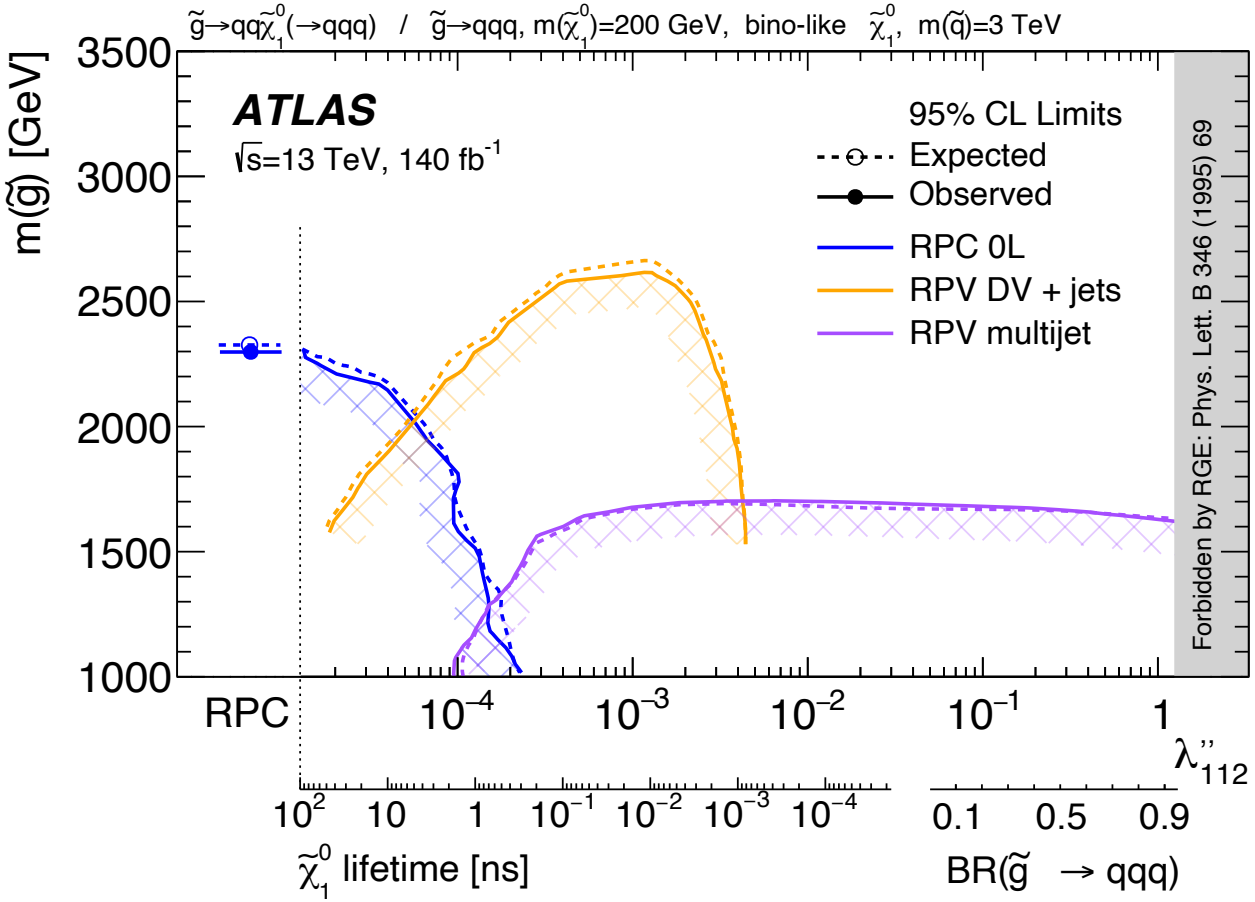
On arXiv yesterday: 2603.15007

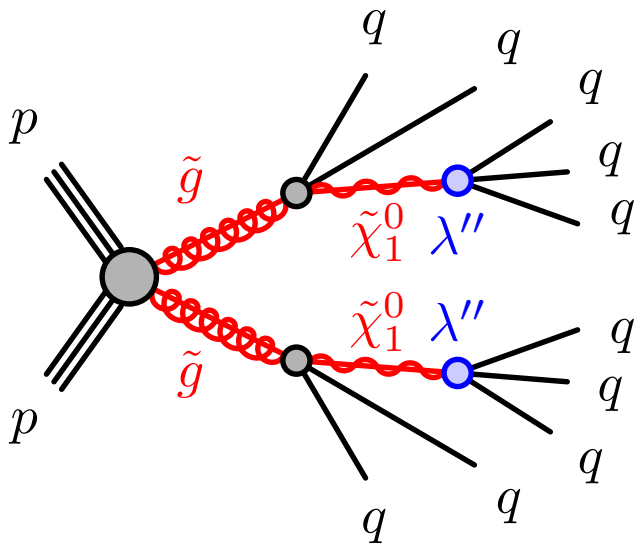
Table 3: Main characteristics of the most sensitive signal region per analysis. Only an illustrative subset of the selections that define each signal region are included here. The definition of different kinematic variables used for these selections is described in Table 2. The τ_{had}^{M} (τ_{had}^{T}) refers to τ_{had} passing the `Medium` (`Tight`) identification working points [85]. A dash (–) is used to indicate that the variable is not used in the analysis selection. The requirement of two same-sign leptons is denoted as SS. The $\text{OS}_{1,2}$ means that the leading and second leading taus in terms of transverse momentum must have opposite sign. The definition of the different kinematic variables used for cuts indicated in the table can be found in the corresponding publications for the input analyses. The RECAST column indicates that the entry is a recast result, not the original analysis.

Analysis name	$\ell/\tau_{\text{had}}^{M}/\tau_{\text{had}}^{T}$	Jets / b-tags	$E_{\text{T}}^{\text{miss}}$ selection	Representative cuts	Model targeted	RECAST
RPV MJ [100]	0 / – / –	≥ 8 / ≥ 2	–	$C \geq 0.85$	Gqq+UDD	No
RPC 0L, 2-6 jets [87]	0 / – / –	≥ 6 / –	$E_{\text{T}}^{\text{miss}}/\sqrt{H_T} > 10$	$m_{\text{eff}} > 3400$ GeV	Gqq+LQD Gqq+UDD	Yes
RPV DV+jets [88]	–	≥ 4 / –	–	$R_{DV} < 300$ mm	Gqq+UDD, Gtt, Stop	No
RPC multi-b [101]	0 / – / – 1 / – / –	≥ 5 / ≥ 3 ≥ 4 / ≥ 3	$E_{\text{T}}^{\text{miss}} > 600$ GeV $E_{\text{T}}^{\text{miss}} > 300$ GeV	$m_{\text{eff}} > 2900$ GeV $m_{\text{eff}} > 800$ GeV	Gtt	Yes
RPV SS/3L [102]	2 SS / – / –	≥ 5 / – ≥ 6 / = 1 ≥ 5 / ≥ 2	–	$m_{\text{eff}} > 2600$ GeV $\sum p_{\text{T}}^{\text{jet}} > 1600$ GeV $\sum p_{\text{T}}^{\text{jet}} > 1600$ GeV	Gqq+LQD, Gtt	No
RPV 1L [103]	1 / – / –	≥ 10 / ≥ 3	–	–	Gtt, Stop	Yes
RPC Stop 0L [89]	0 / – / –	≥ 4 / ≥ 2	$E_{\text{T}}^{\text{miss}} > 250$ GeV	$m_1^{R=1.2} > 120$ GeV	Stop	Yes
RPV stop dijet [90]	–	≥ 4 / ≥ 2	–	$\mathcal{A} < 0.05$	Stop	No
RPV dijet resonance [104]	–	≥ 2 / ≥ 2	–	$m_{jj} > 1133$ GeV	Stop	No
RPV multi-b [105]	0 / – / –	≥ 9 / ≥ 5	–	–	Gtt	No
RPC Di-τ [93]	– / = 2, $\text{OS}_{1,2}$ / ≥ 1	– / veto	∈ [60, 150] GeV	$m_{\text{T2}} > 80$ GeV	Stau, Higgsino	No
	– / = 2, $\text{OS}_{1,2}$ / –	– / veto	> 150 GeV	$m_{\text{T2}} > 85$ GeV $m_{\text{Tsum}} > 400$ GeV		
	– / ≥ 2, $\text{OS}_{1,2}$ / ≥ 1	– / veto	∈ [60, 150] GeV	$m_{\text{T2}} > 70$ GeV		
	– / ≥ 2, $\text{OS}_{1,2}$ / –	– / veto	> 150 GeV	$m_{\text{T2}} > 85$ GeV $m_{\text{Tsum}} > 400$ GeV		
RPC/RPV 4L [94]	≥ 4 / ≥ 0 / –	– / veto	> 100 GeV > 200 GeV –	– $m_{\text{eff}} > 600$ GeV $m_{\text{eff}} > 1250$ GeV	Stau, Higgsino	Yes
	= 3 / ≥ 1 / –	– / veto	–	$m_{\text{eff}} > 600$ GeV $m_{\text{eff}} > 1000$ GeV		
	= 2 / ≥ 2 / –	– / veto	–	$m_{\text{eff}} > 600$ GeV $m_{\text{eff}} > 1000$ GeV		
RPC DL [106]	2 / – / –	– / –	–	$\Delta R_{\ell\ell} > 0.2$	Higgsino	Yes

Reinterpretation: conservation to violation of *R*-parity

On arXiv yesterday: 2603.15007

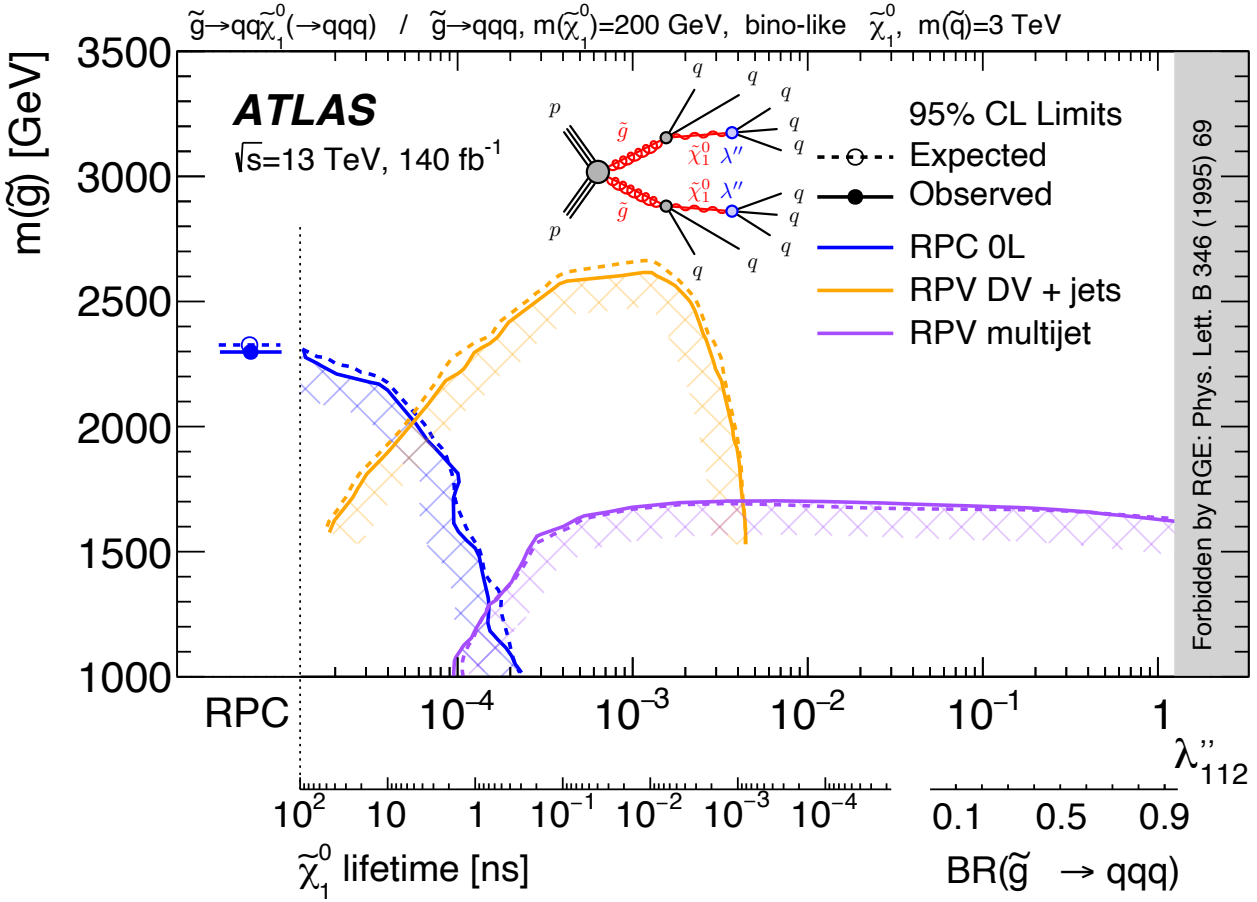


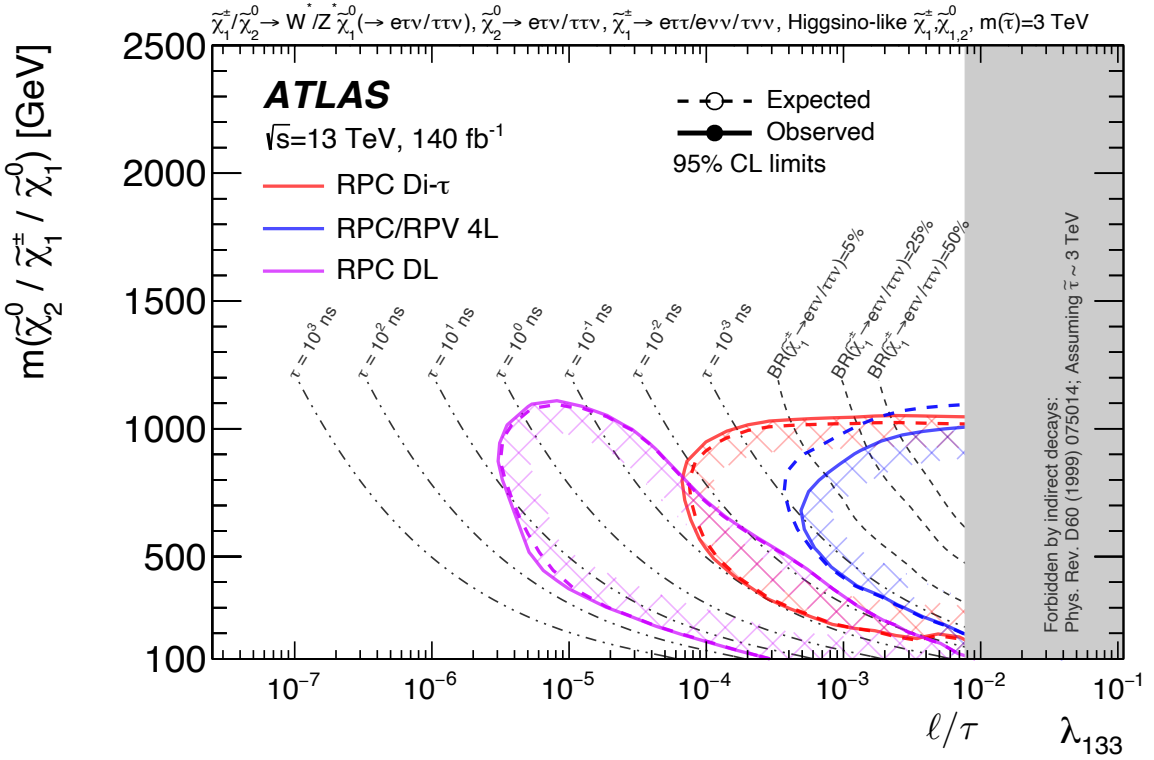


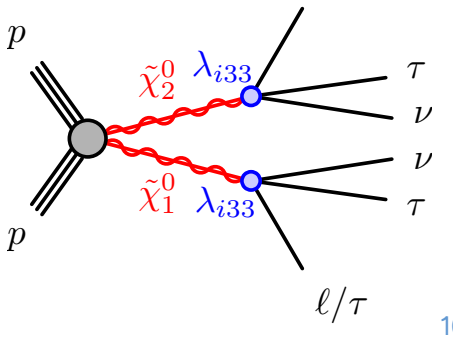
- Smaller RPV coupling → longer LSP lifetime: prompt → long-lived → $E_{\mathrm{T}}^{\mathrm{miss}}$
- Very large RPV coupling → direct decay instead of cascade

Reinterpretation: conservation to violation of *R*-parity

On arXiv yesterday: 2603.15007







- Smaller RPV coupling → longer LSP lifetime: prompt → long-lived → $E_{\mathrm{T}}^{\mathrm{miss}}$
- Very large RPV coupling → direct decay instead of cascade

Concluding remarks

- SUSY remains one of the best motivated and most extensively studied SM extensions
  - MSSM more and more constrained — but *SUSY still attractive theoretical principle*
  - Flashed *7 recent results* from ATLAS and CMS excluding new interesting parameter space
  - Interesting regions remain allowed → *targeted efforts and careful experimental work*
  - Great Swiss army knife for *spanning space of experimental signatures*

- Many talks tomorrow will cover more SUSY results!
  - New physics with photons
  - Displaced Vertices & unconventional signatures
  - ATLAS wildcard

- For anyone interested in observed excesses in searches: LPCC BSM WG excess page
  - Run 3 underway and will keep pushing sensitivity
  - HL-LHC detector upgrades enable improvements


KTH
VETENSKAP
OCH KONST