SUSY review with ATLAS and CMS experiments

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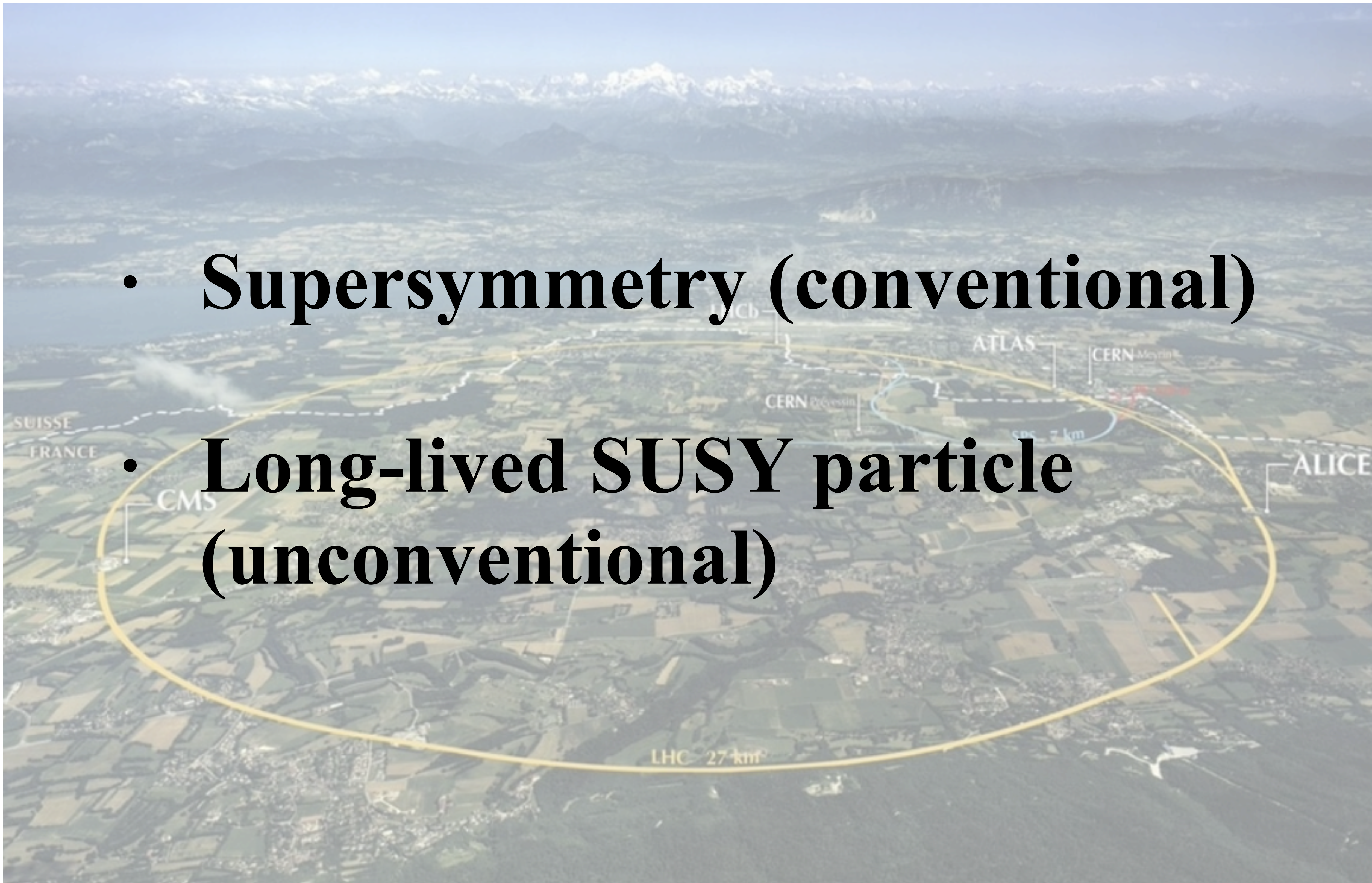
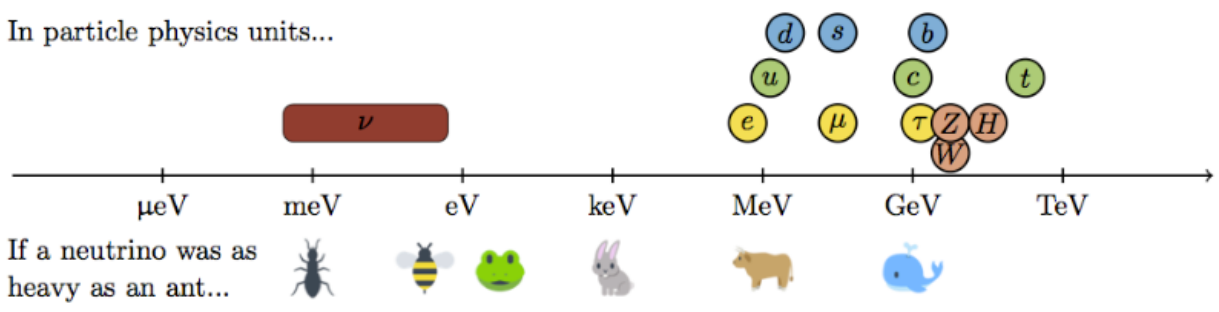
on behalf of ATLAS and CMS experiments
CLHCP 2023

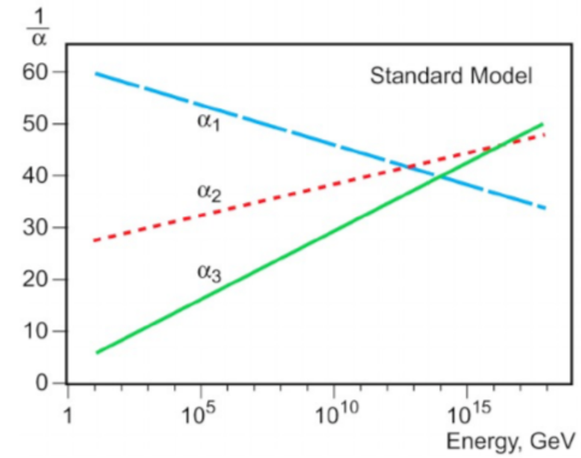
中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

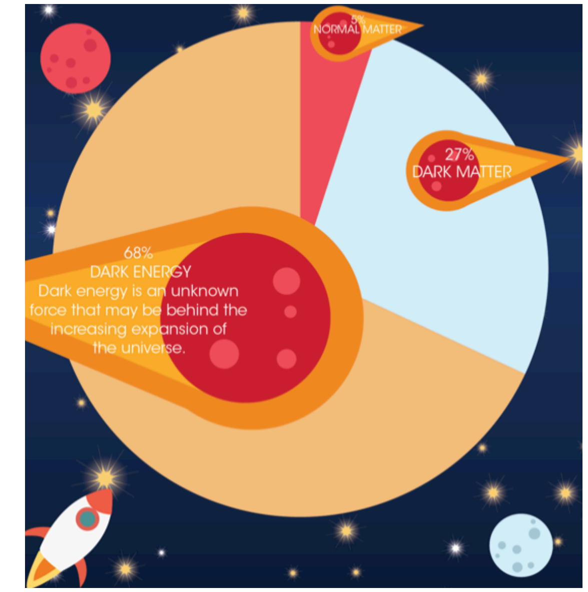
Outline

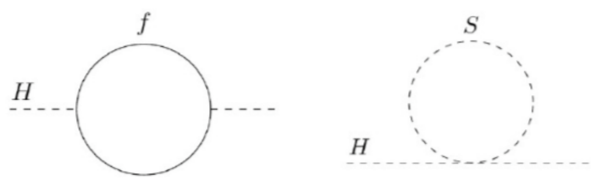


- **Supersymmetry (conventional)**
- **Long-lived SUSY particle (unconventional)**









Supersymmetry

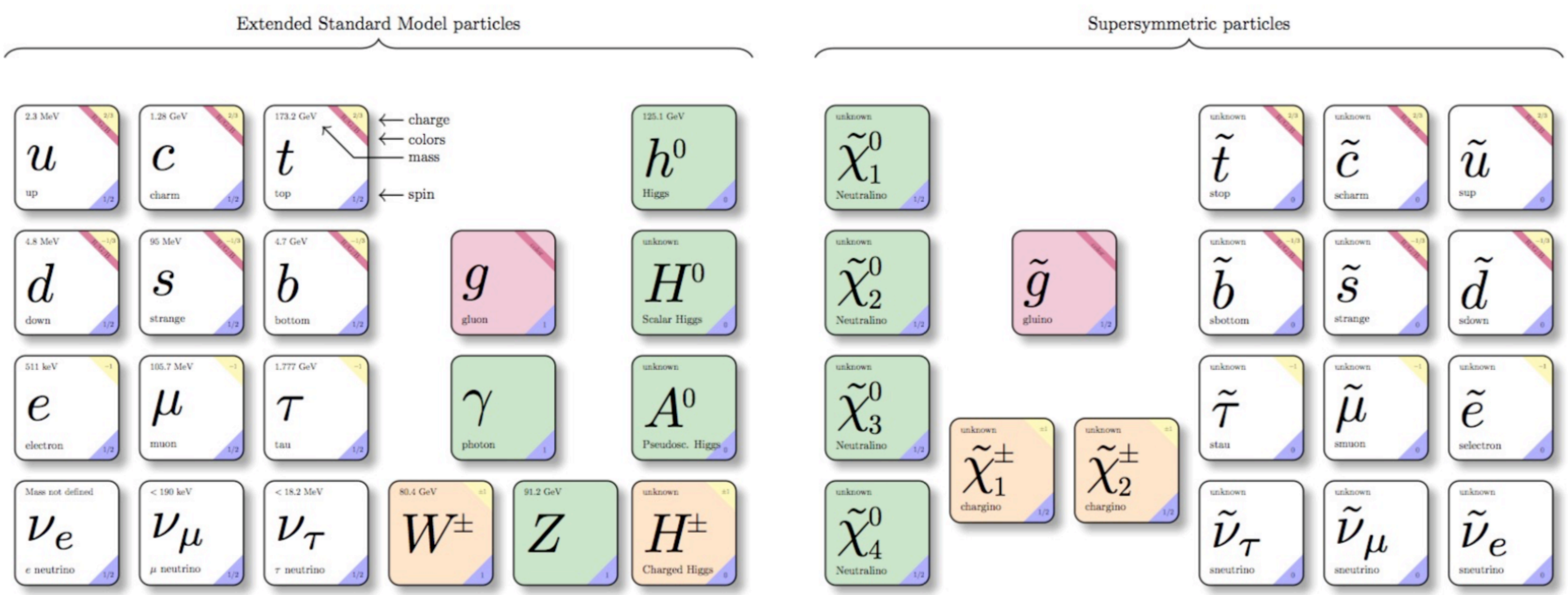
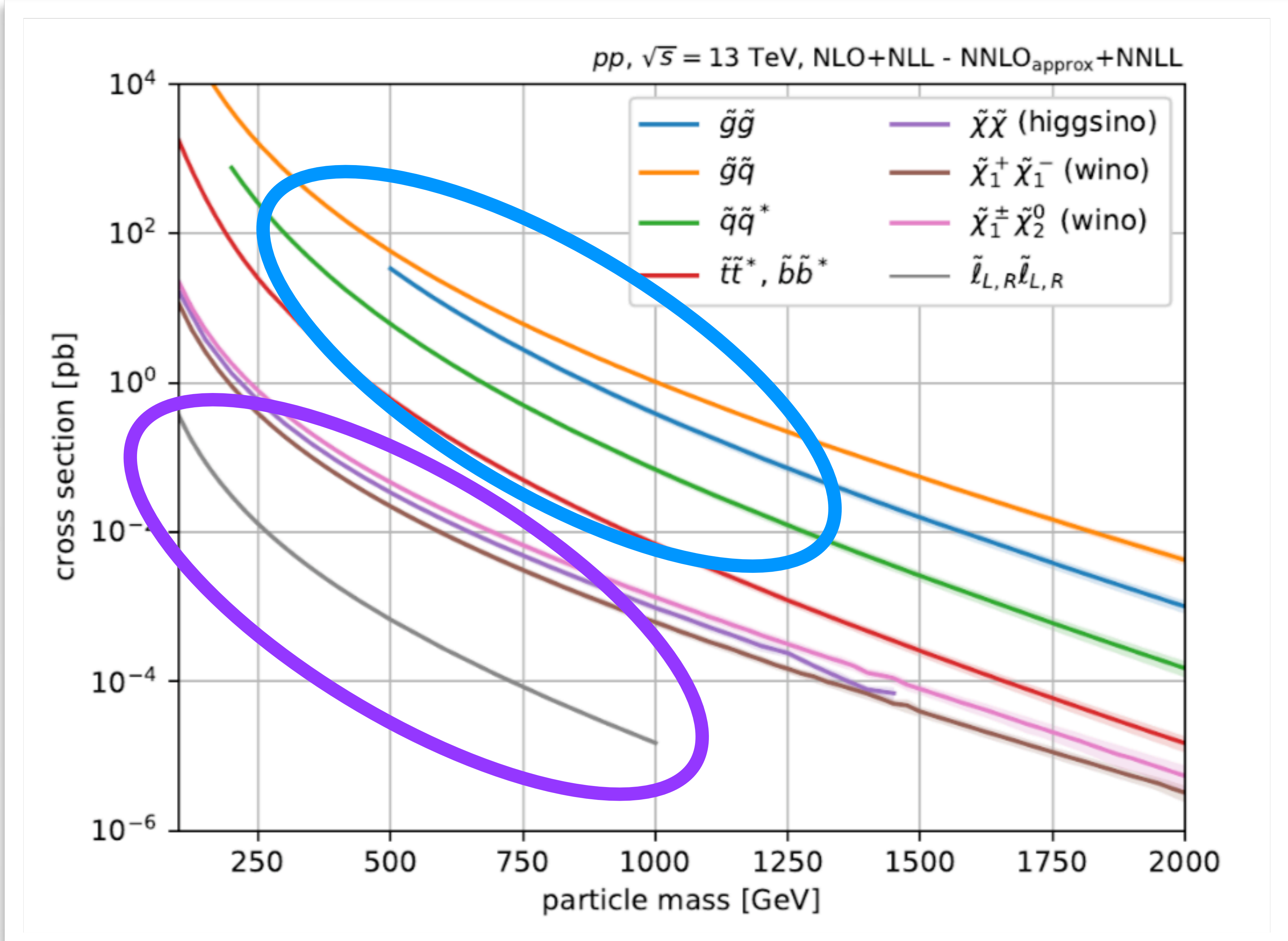


Image credit: M. Rimoldi

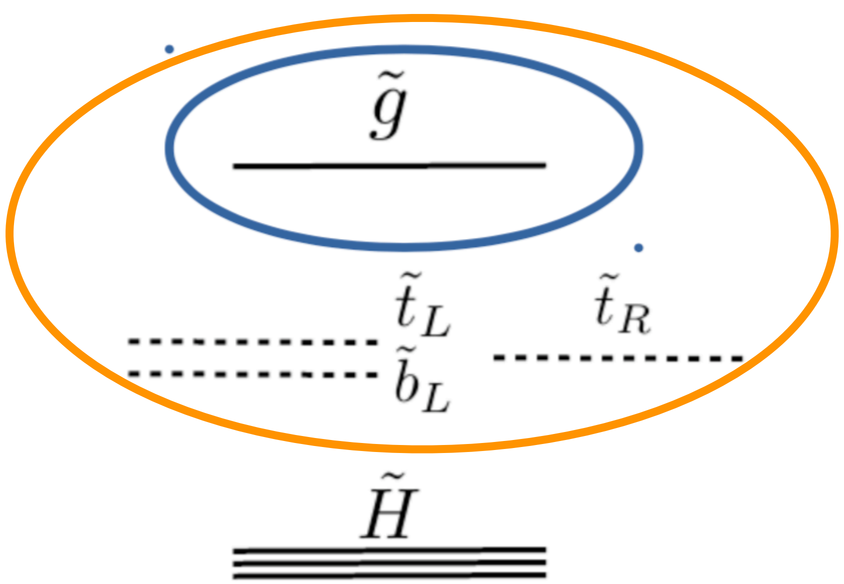
The SUSY production @ 13TeV

Strong SUSY: larger cross-section; energetic jet activity.

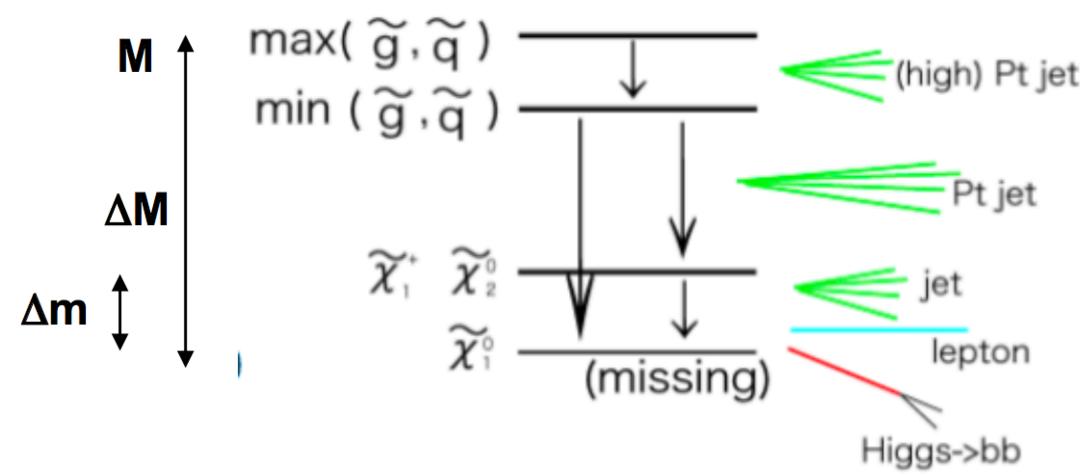


Electroweak SUSY: smaller cross-section; less jet; cleaner signature.

Gluino and squark (incl. 3rd gen)



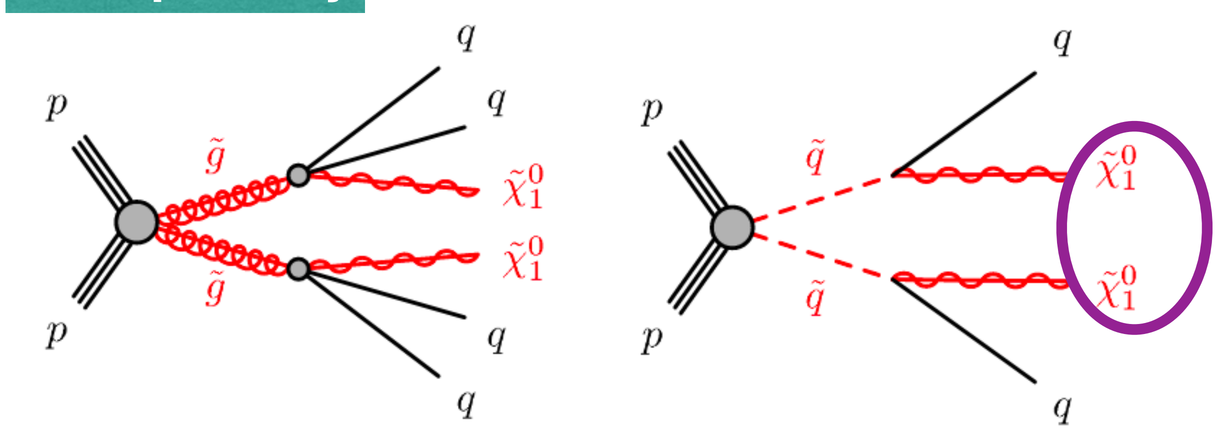
natural SUSY



Benchmark gluino/squark scenarios — I

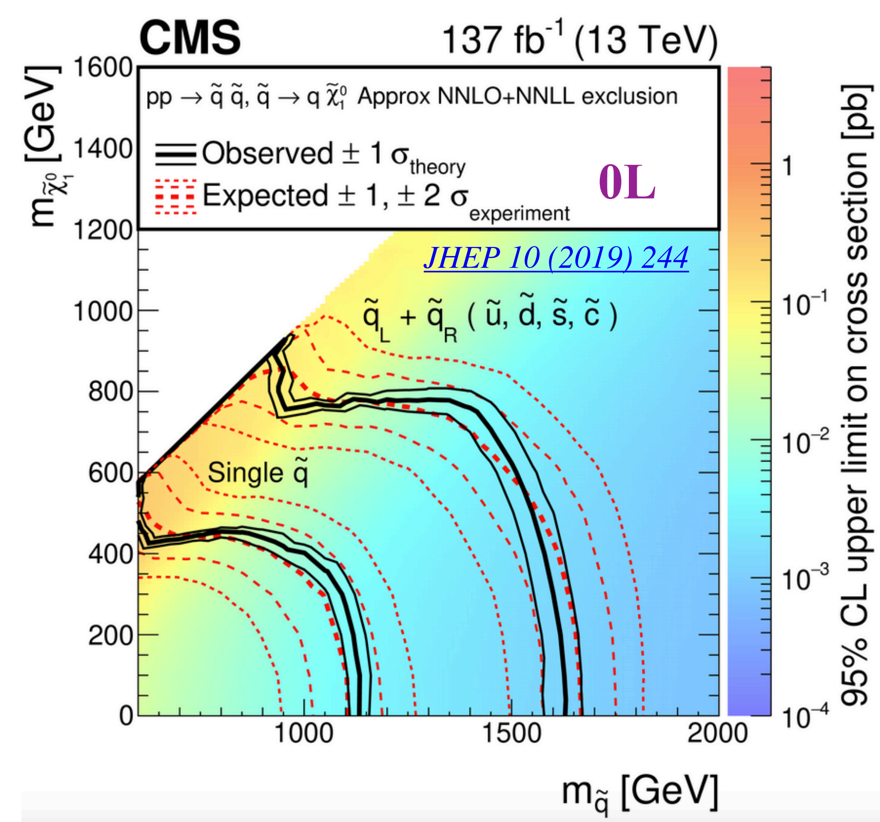
Classic

0-Step decay

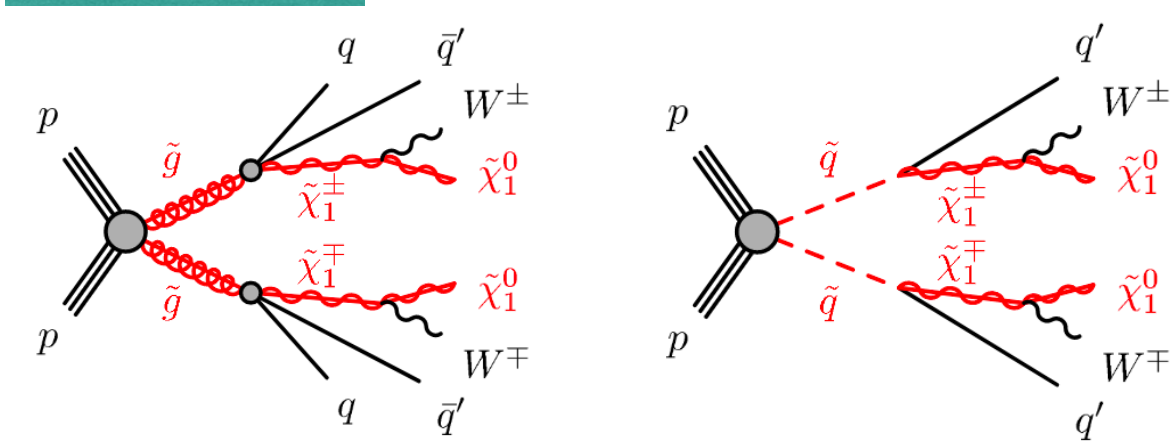


Lightest SUSY Particle (LSP)

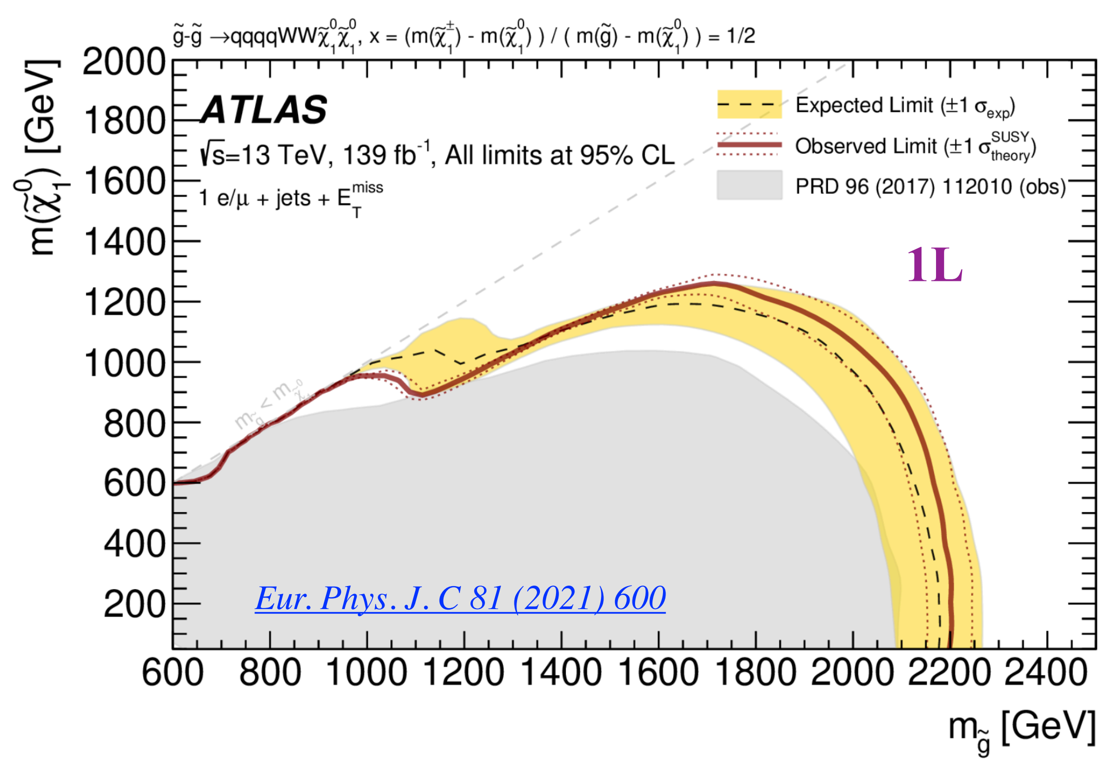
- >= 4 (2) jets for Gluino (Squark)
- Large **MET** from LSP



1-Step decay



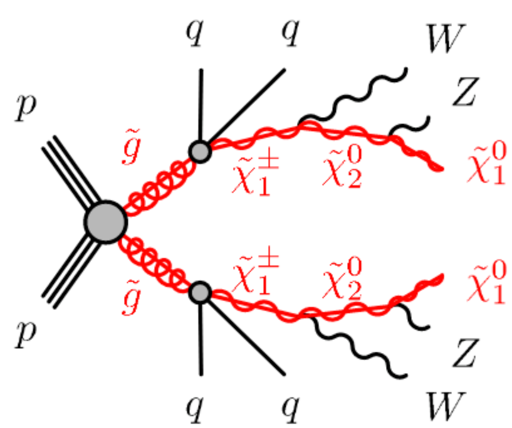
- >= 4-8 (2-6) jets Gluino (Squark)
- Large **MET** from LSP
- W hadronically (0L) or leptonically (1-2L) decay



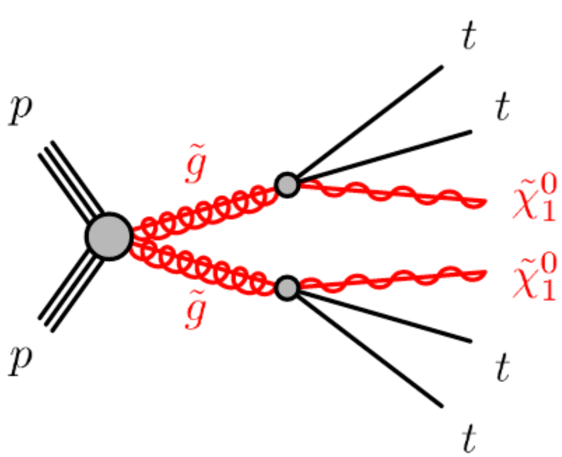
Benchmark gluino/squark scenarios — II

More complicated

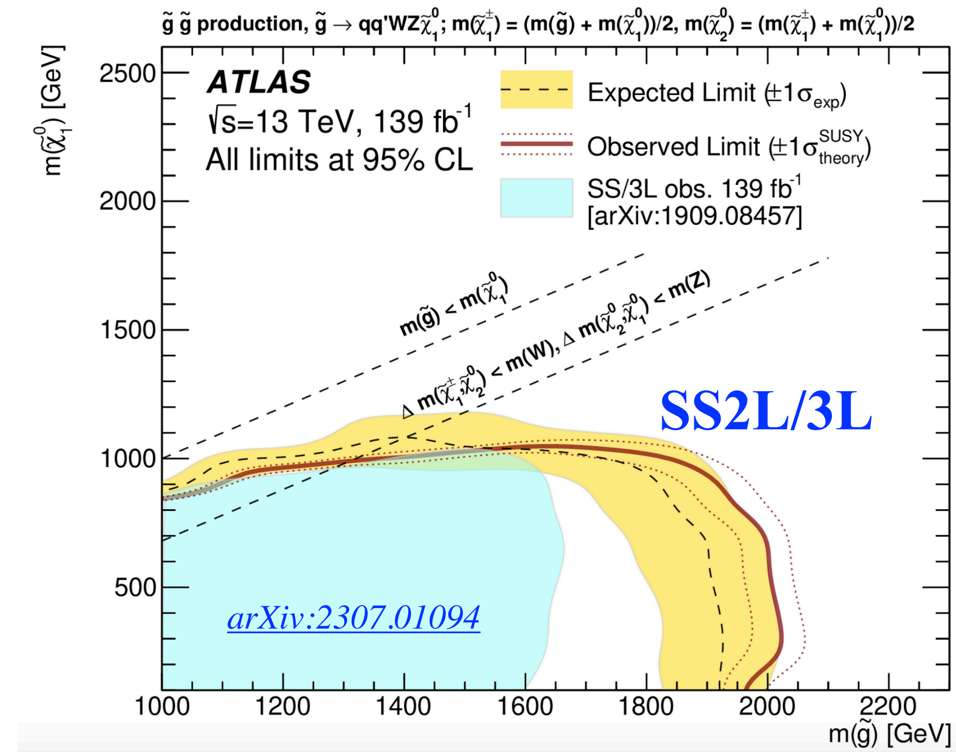
2-Step decay

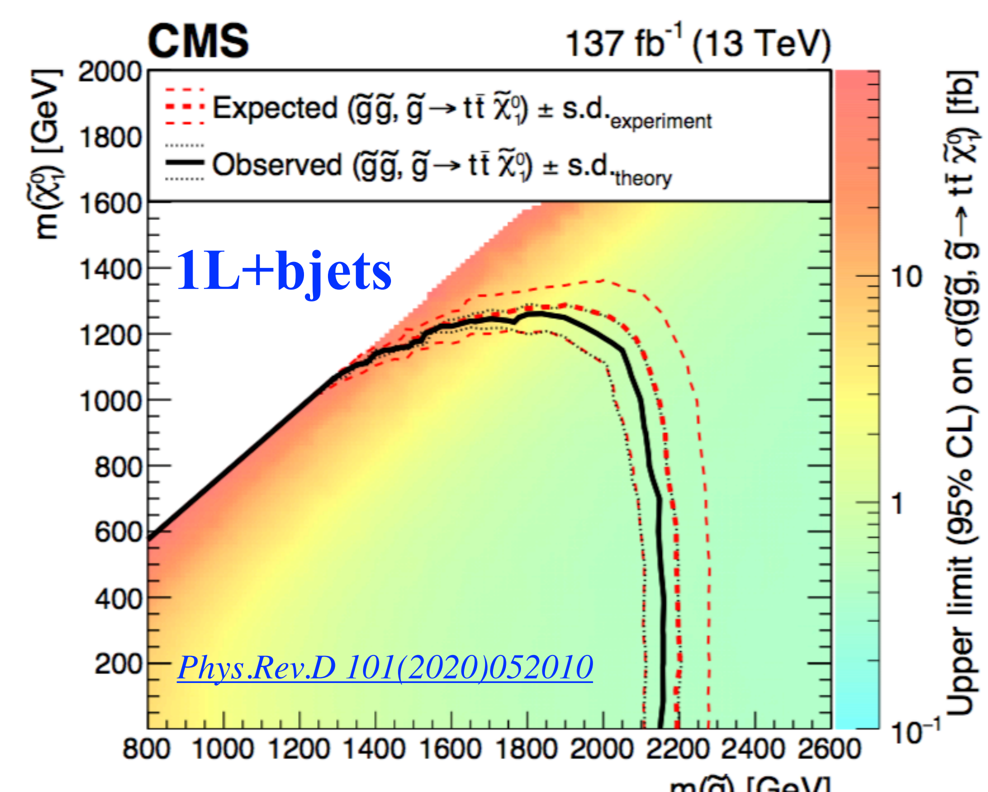


Gtt



- **Long cascade decays of gluinos into large jet activity or multi-leptons**
- **Large jet activity—> events up to 8-12 jets**
- **When leptons come from different decay chain, requiring SS leptons can highly suppress SM**
- **Consider b-tagged jet if top in the decay chain—> event categories in 0,1,2 b-jets**

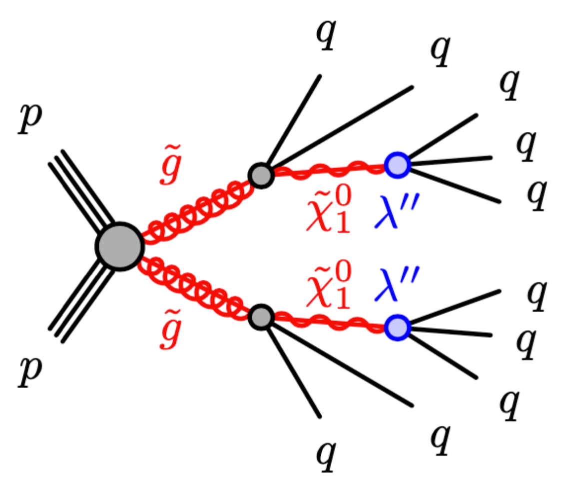


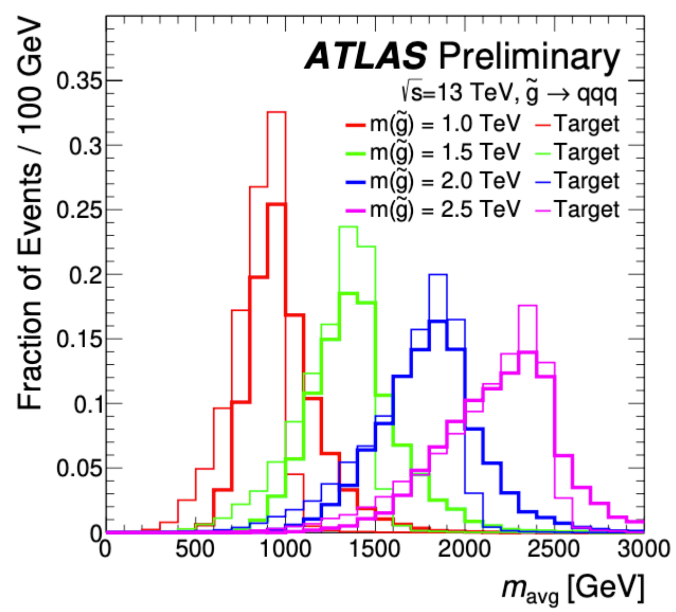


Recent publication

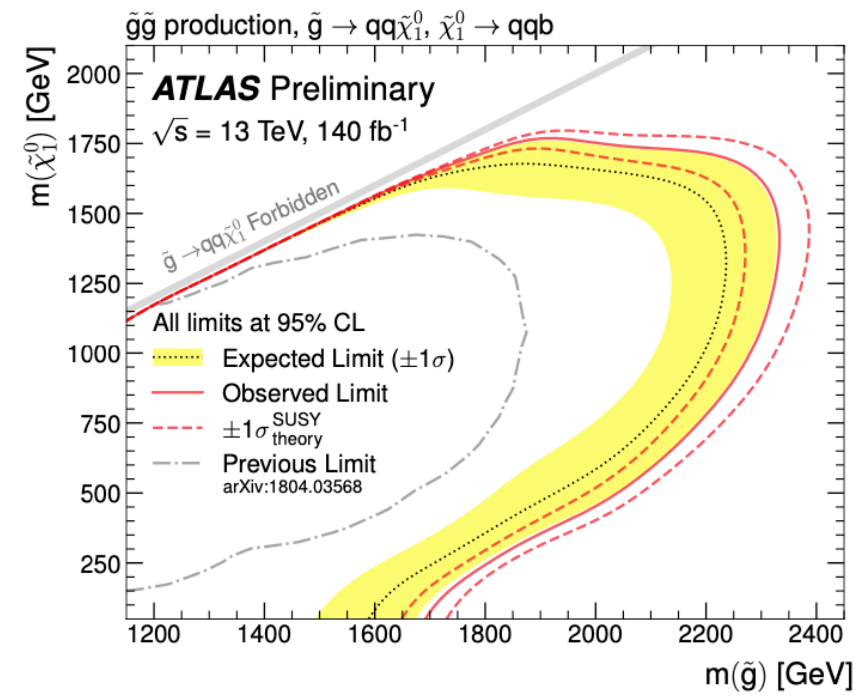
Fresh NEW

Decay involving RPV coupling



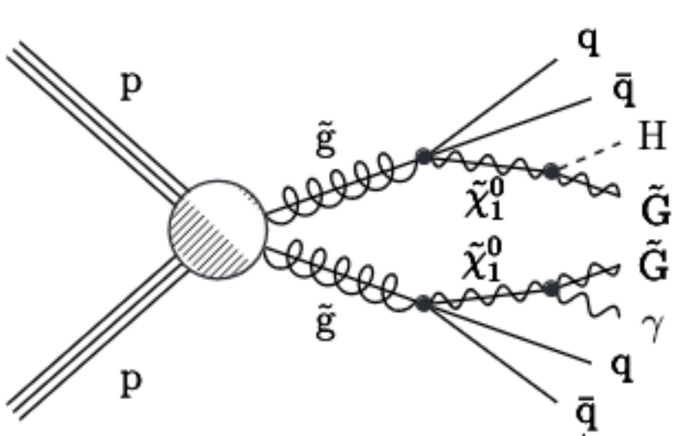


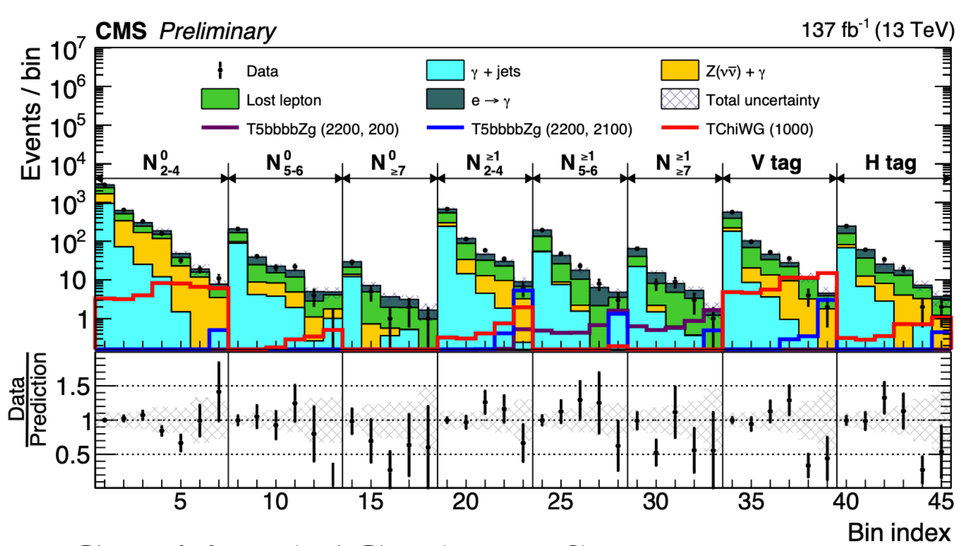
ATLAS-CONF-2023-049



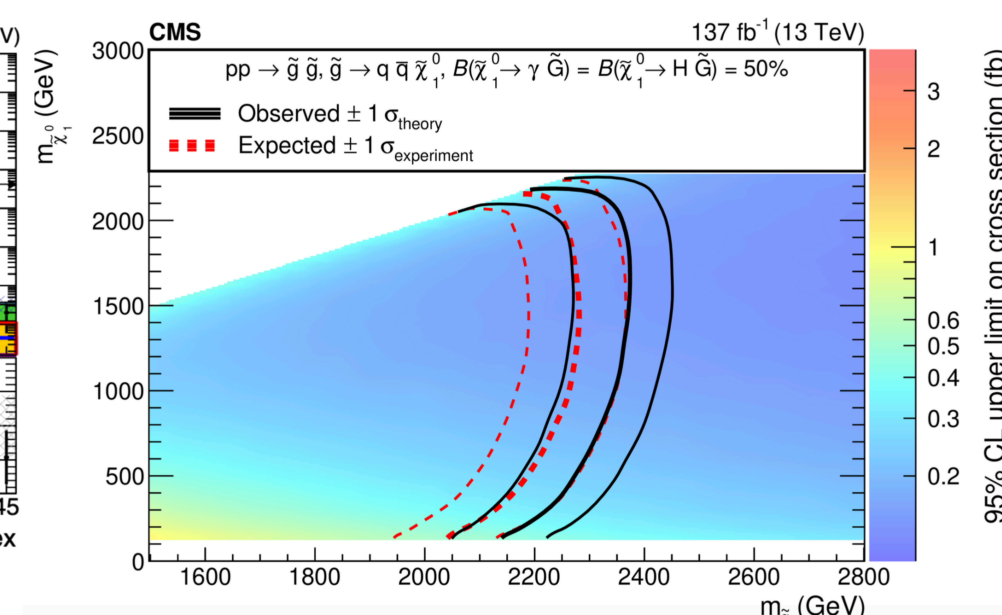
- Free of MET constraint —> gain in soft decay products
- Reconstruct the avg. gluino mass resonance w/ NN

Decay involving Gravitino



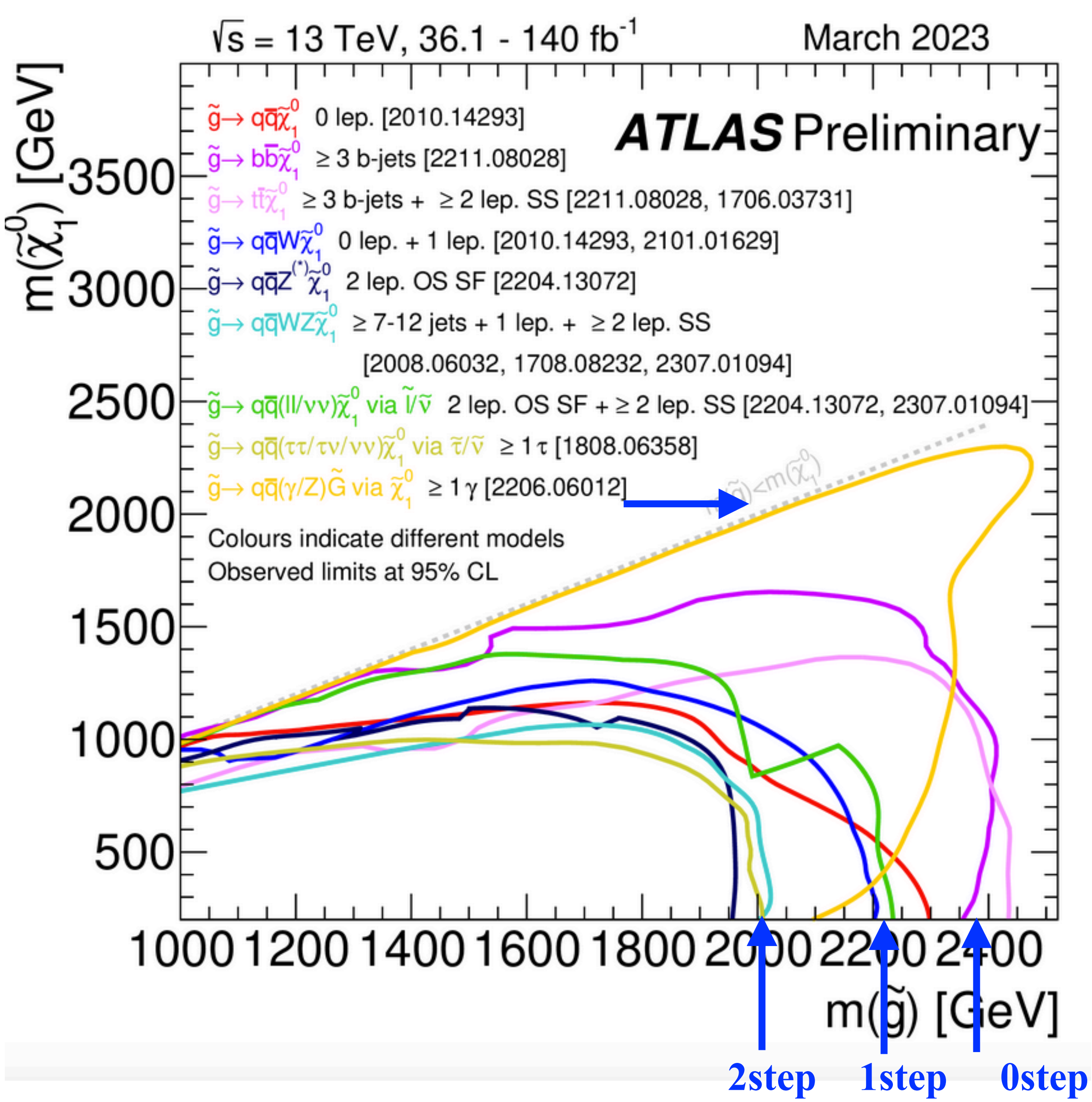


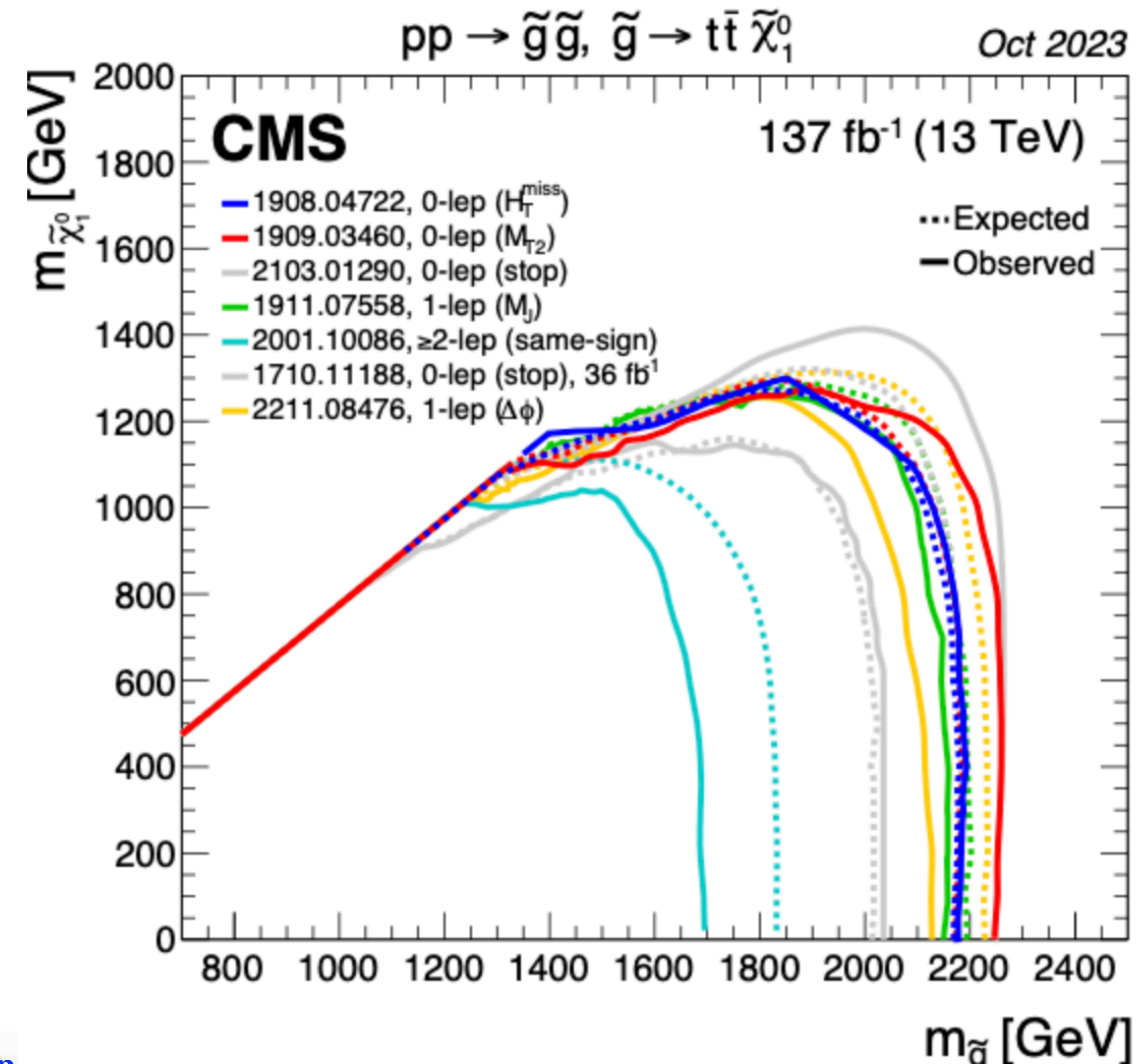
CMS-SUS-21-009



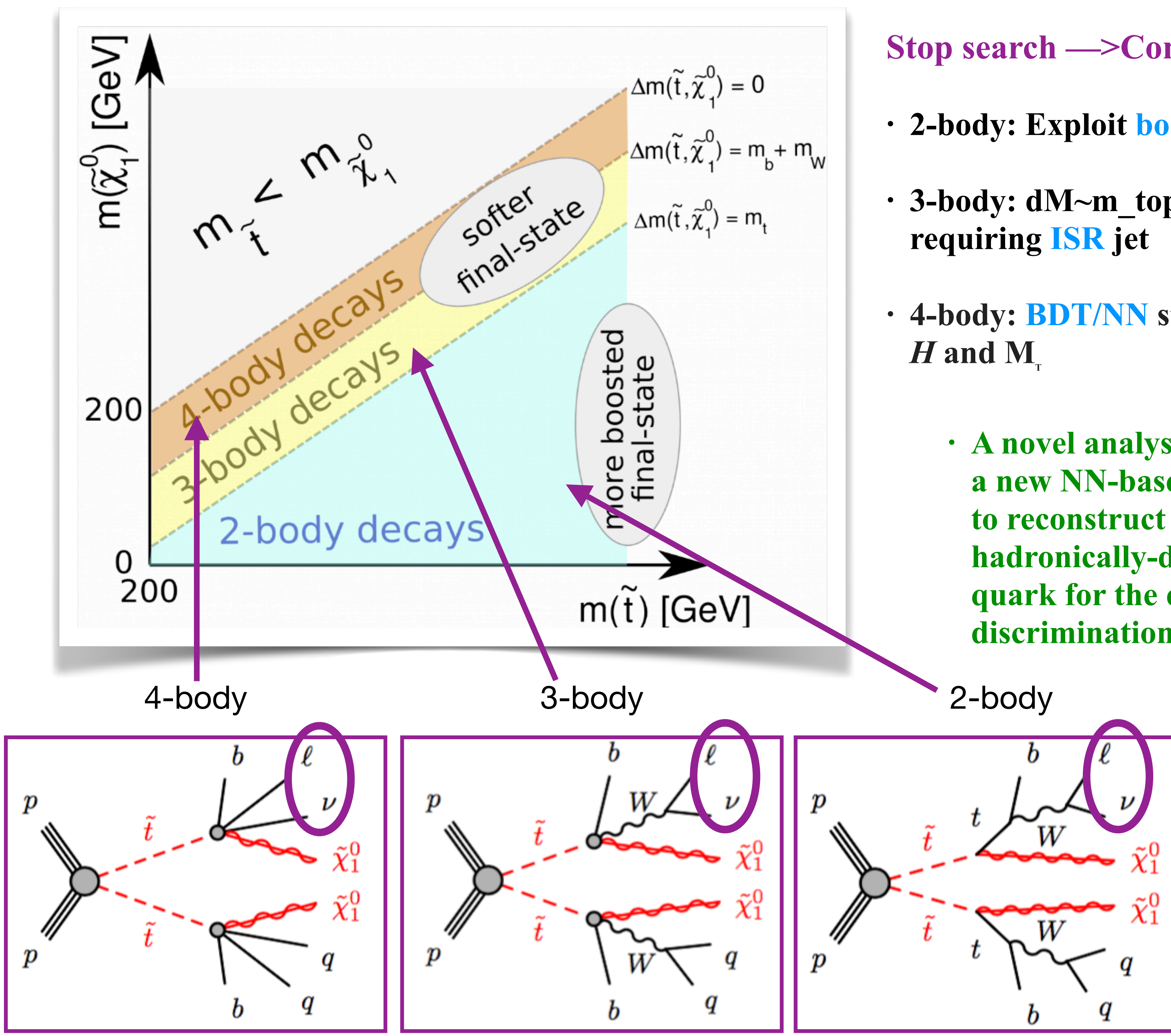
- N1 as NLSP decays into a Gravitino (~1GeV) as LSP
- H-tagger is used

Gluino summary





3rd generation: Stop search

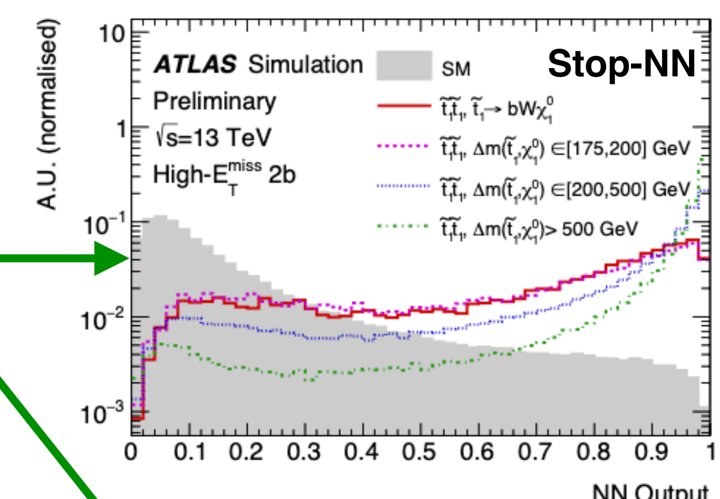


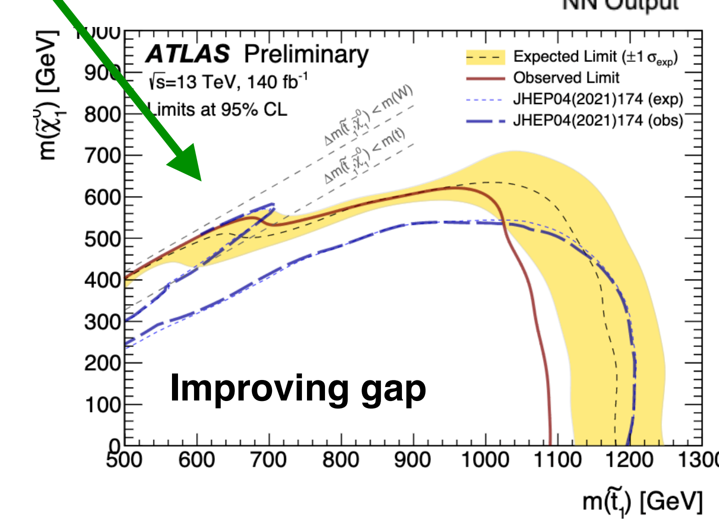
Stop search —>Complex decay topologies due to large top mass

- **2-body: Exploit boost top reconstruction using largeR jet**
- **3-body: dM~m_top, main background ttbar <— separation via requiring ISR jet**
- **4-body: BDT/NN strategy, i.e. trained based on p_T (l), p_T^{miss}, p_T (ISR), H_T and M_T**

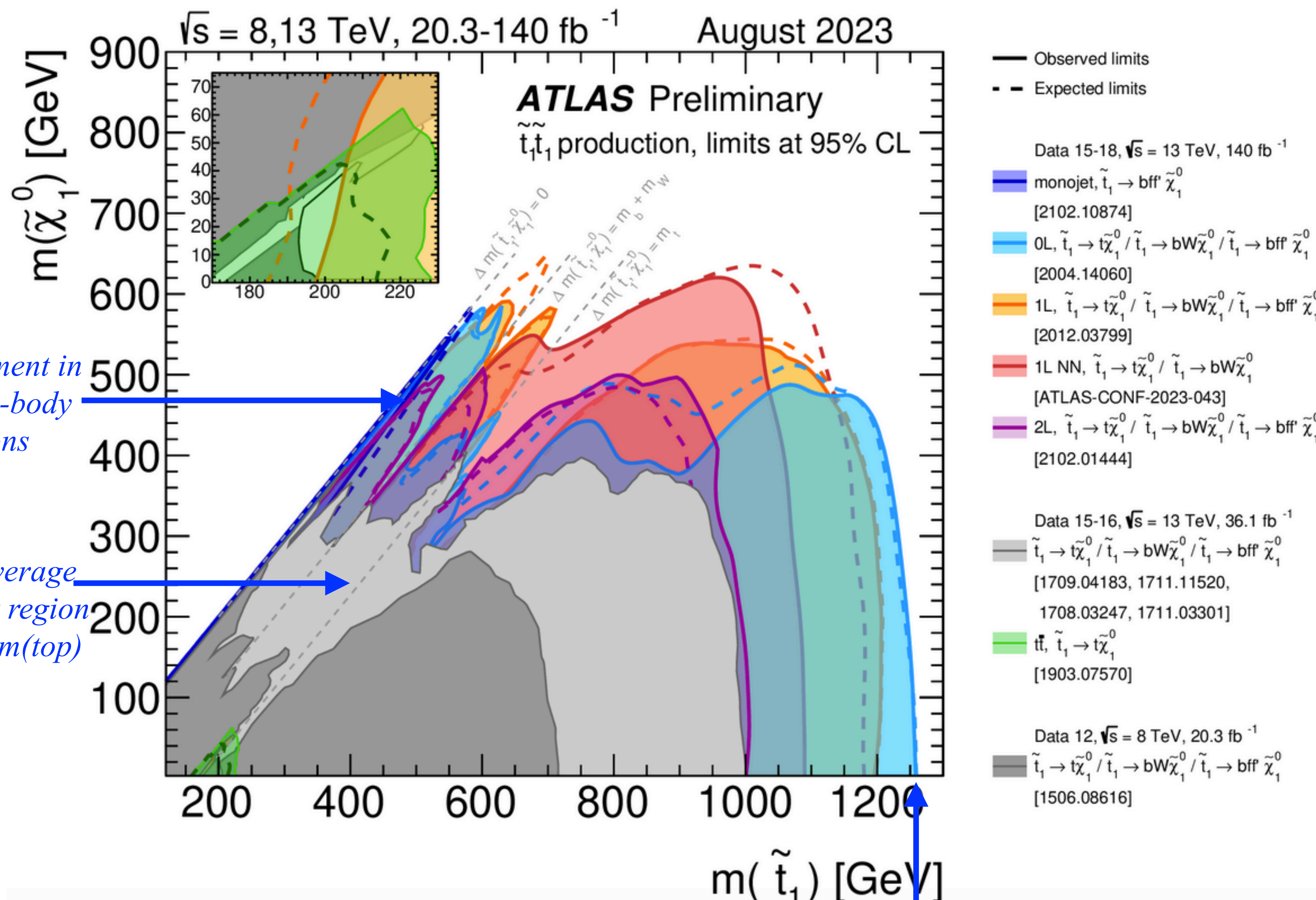
ATLAS-CONF-2023-043

- **A novel analysis developed a new NN-based classifiers to reconstruct the hadronically-decaying top quark for the event discrimination**





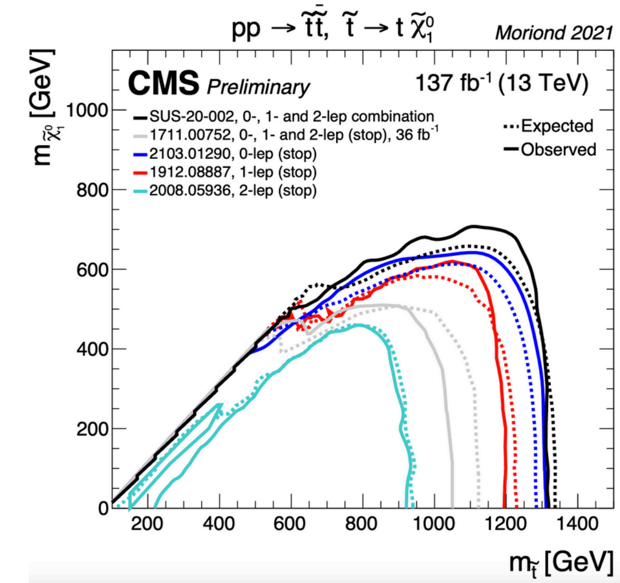
Stop summary

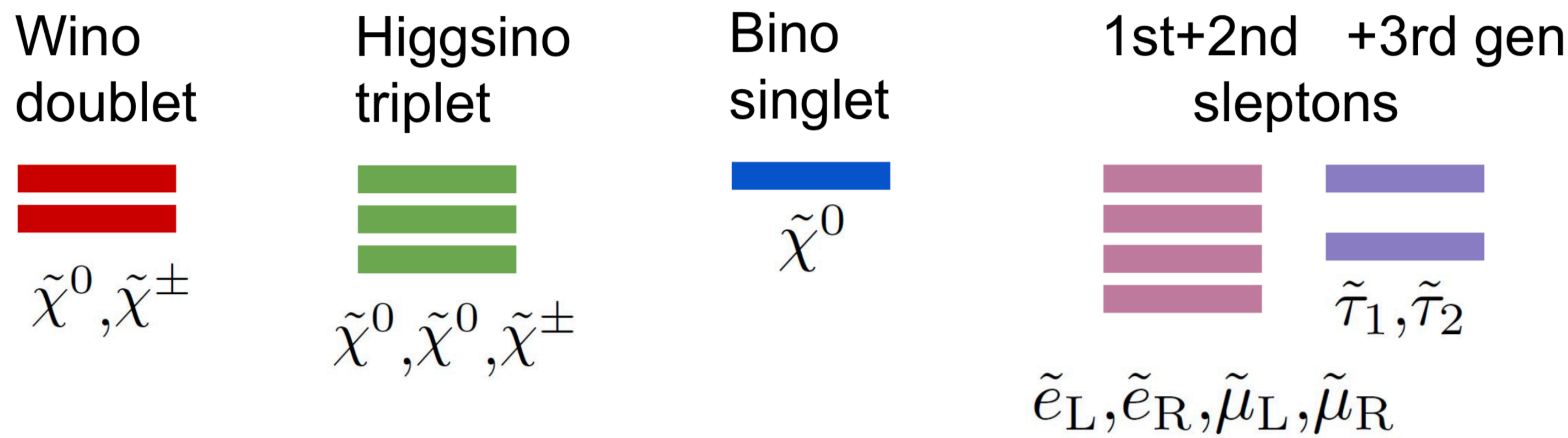


Improvement in 3- and 4-body regions

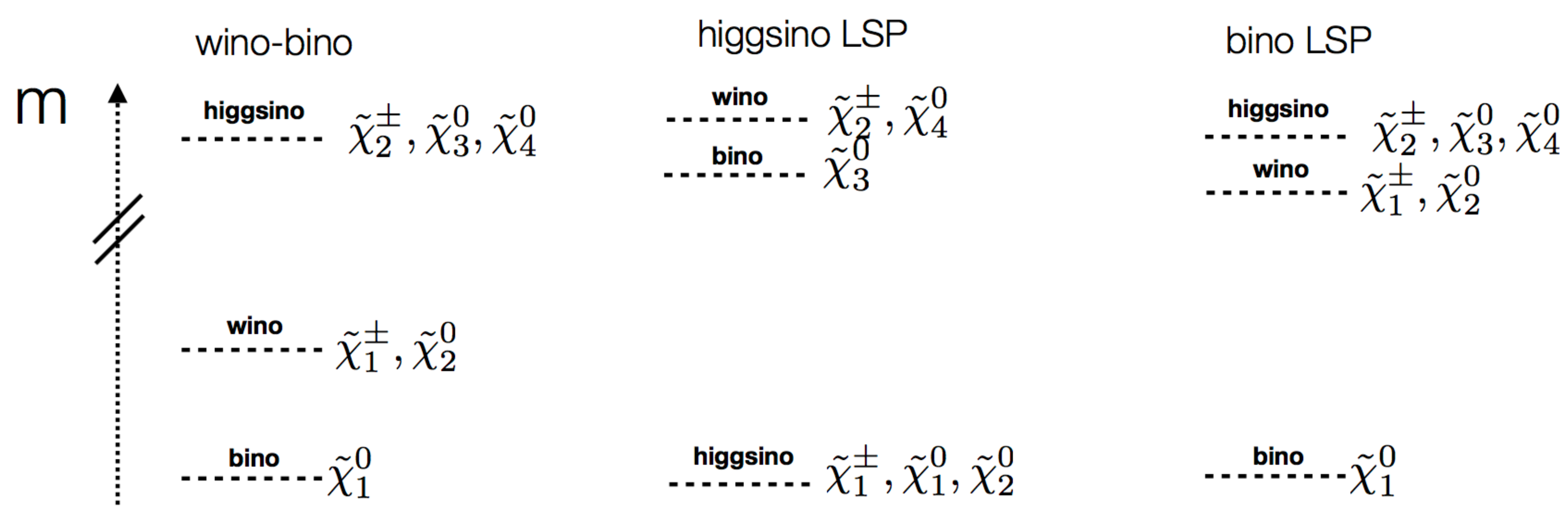
Good coverage of difficult region with dM~m(top)

Reaching significantly higher stop masses





Electroweakino



Phenomenology depends on wino-bino-higgsino mixing, mass hierarchy, and decay channels.

NEW! EWK combination

ATLAS combination channels

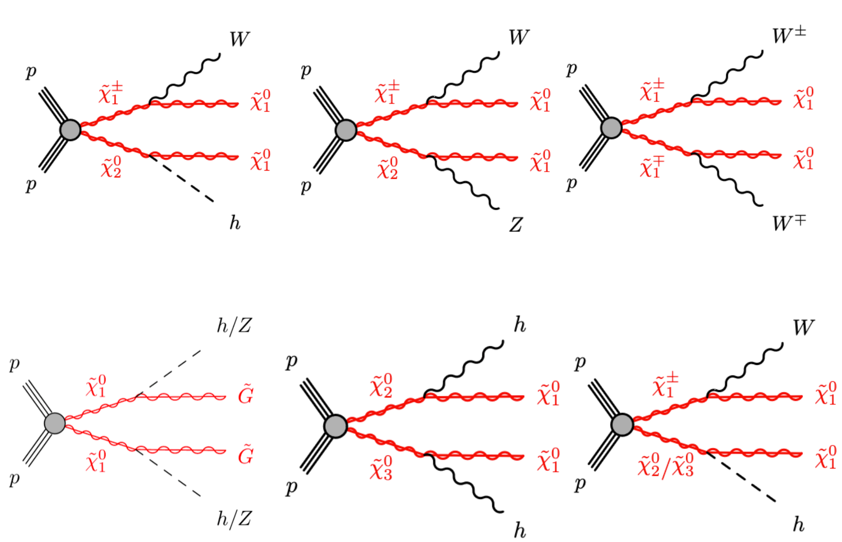
ATLAS-CONF-2023-046

Production mode	Wino $\tilde{\chi}_1^+\tilde{\chi}_1^-$	Wino $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$	Wino $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$	Higgsino GGM $\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^\pm\tilde{\chi}_{1,2}^0, \tilde{\chi}_1^0\tilde{\chi}_2^0$
Decay mode	$\tilde{\chi}_1^\pm \to W^\pm\tilde{\chi}_1^0$	$\tilde{\chi}_1^\pm \to W^\pm\tilde{\chi}_1^0$ $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$	$\tilde{\chi}_1^\pm \to W^\pm\tilde{\chi}_1^0$ $\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0$	$\tilde{\chi}_1^0 \to Z/h\tilde{G}$
Searches				
All Hadronic [23]	✓	✓	✓	✓
1L [24]	✓	✓		
1Lbb [25]			✓	
2L Compressed [26]		✓		
2L0J $\Delta m > m(W)$ [27]	✓			
2L0J $\Delta m \sim m(W)$ [28]	✓			
2L2J [29]		✓		✓
2tau [30]			✓	
3L [31]		✓	✓	
SS/3L [32]		✓	✓	
4L [33]				✓
Multi-b [34]				✓

- **So far most of the single-channel analyses have released the full Run2 results.**
- **It is essential to look into the statistical combination instead of simply figure overlaying.**
- **Both ATLAS and CMS recently released the statistical combinations of the Run 2 electroweak SUSY searches!**

CMS combination channels

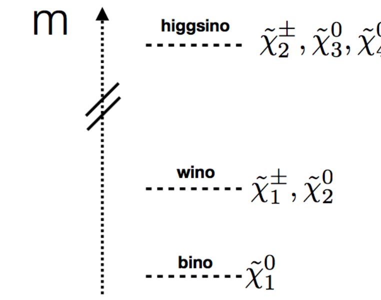
CMS-PAS-SUS-21-008



Search	gaugino WZ	gaugino WH	GMSB ZZ	GMSB HZ	GMSB HH	higgsino-bino WW	higgsino-bino HH	higgsino-bino WH	sleptons $\ell^+\ell^-$
$2/3\ell$ soft [17]	all								2ℓ soft
2ℓ on-Z [15]	EW		EW	EW					
2ℓ non-res. [15]									Slepton
$\geq 3\ell$ [18]	SS, A(NN)	SS, A–F	all	all	all			SS, A–F	
$1\ell 2b$ [16]		all						all	
4b [19]					all		3-b, 4-b, 2-bb		
Hadr. WX [20]	all	b-tag				b-veto		b-tag	

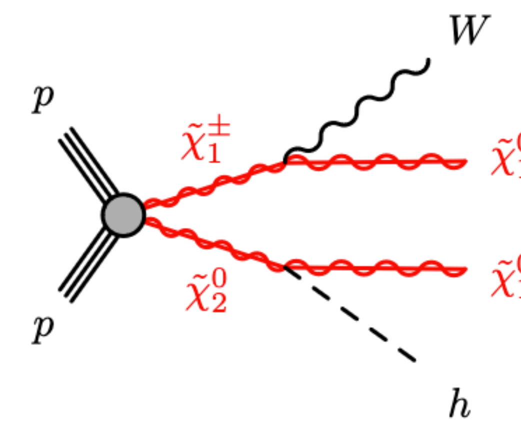
Wino-bino model

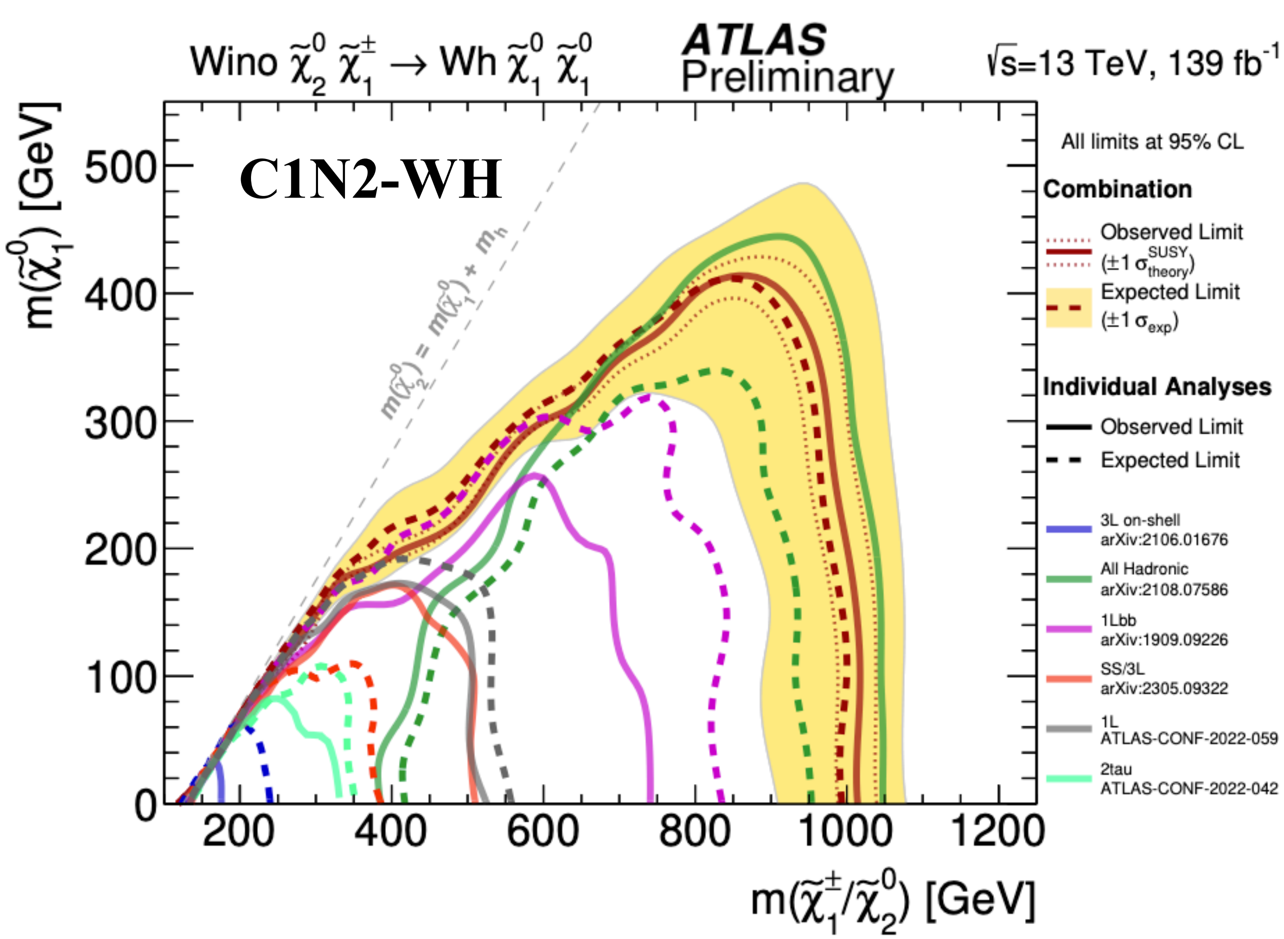
- Decay via W/H

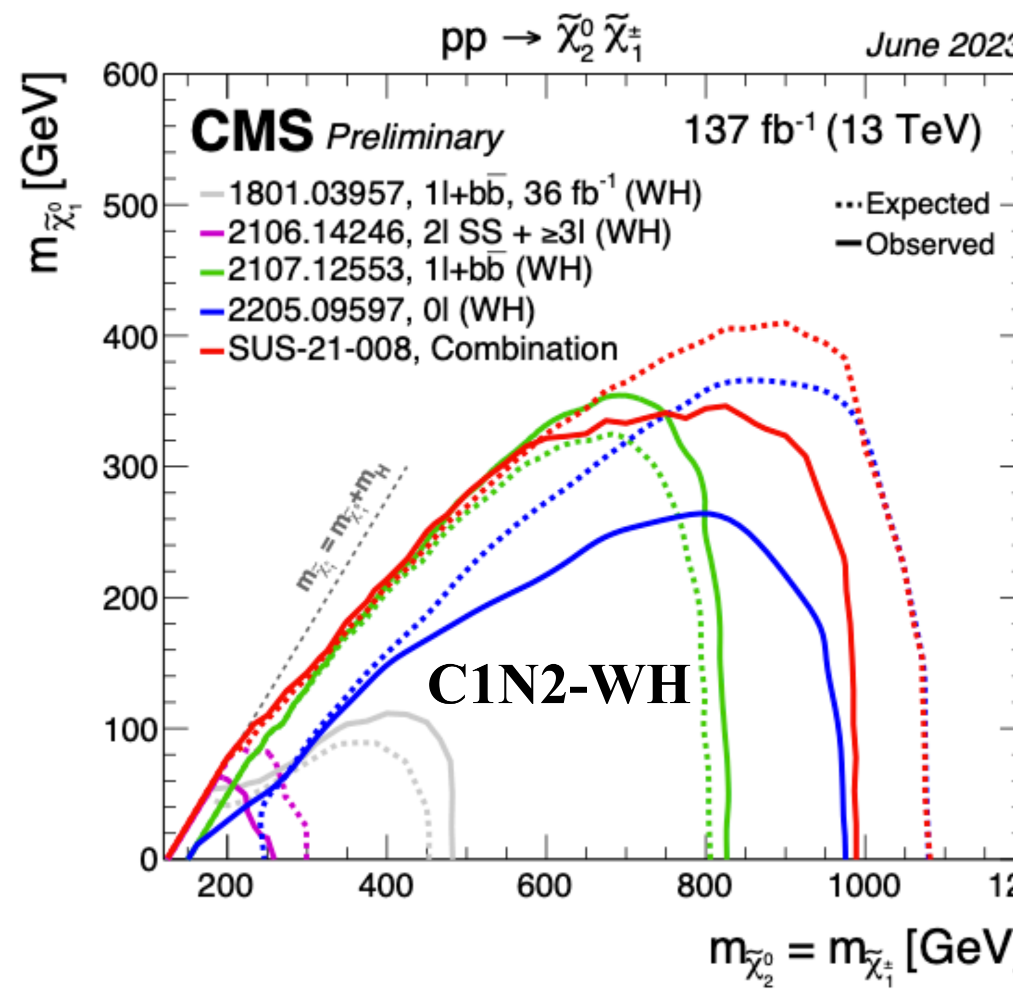


- Statistic combination performed for all orthogonal channels; the best performing search is used *where any overlaps remain*

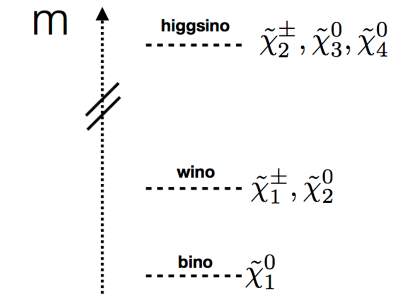
- Similar limit reach obtained for ATLAS and CMS (~1TeV for massless LSP)



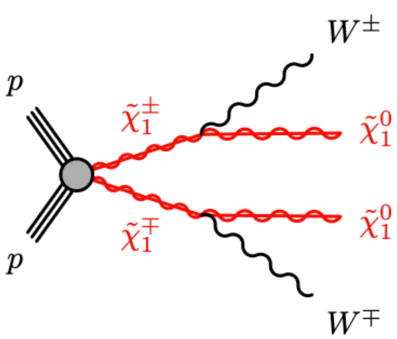


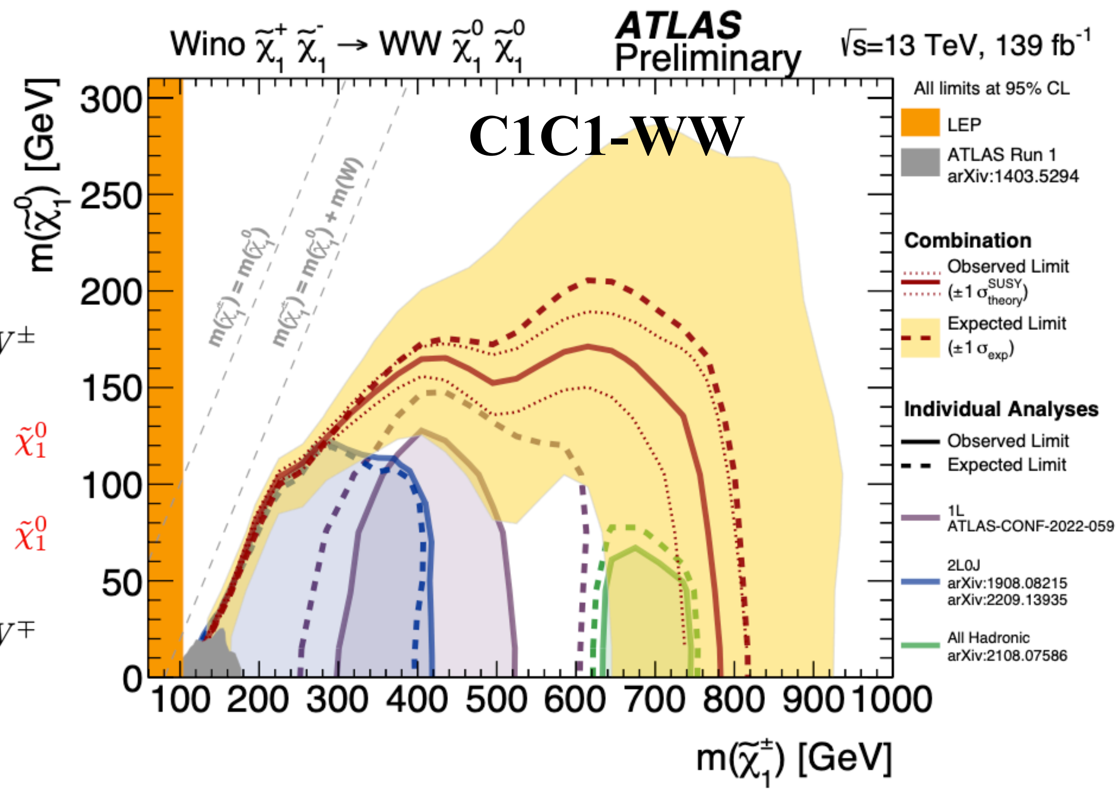


Wino-bino model

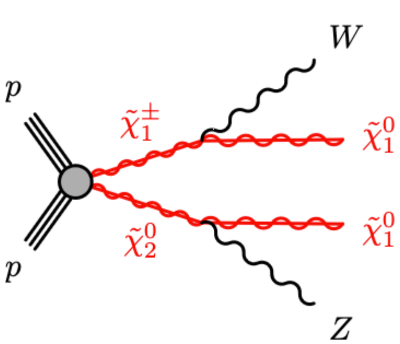


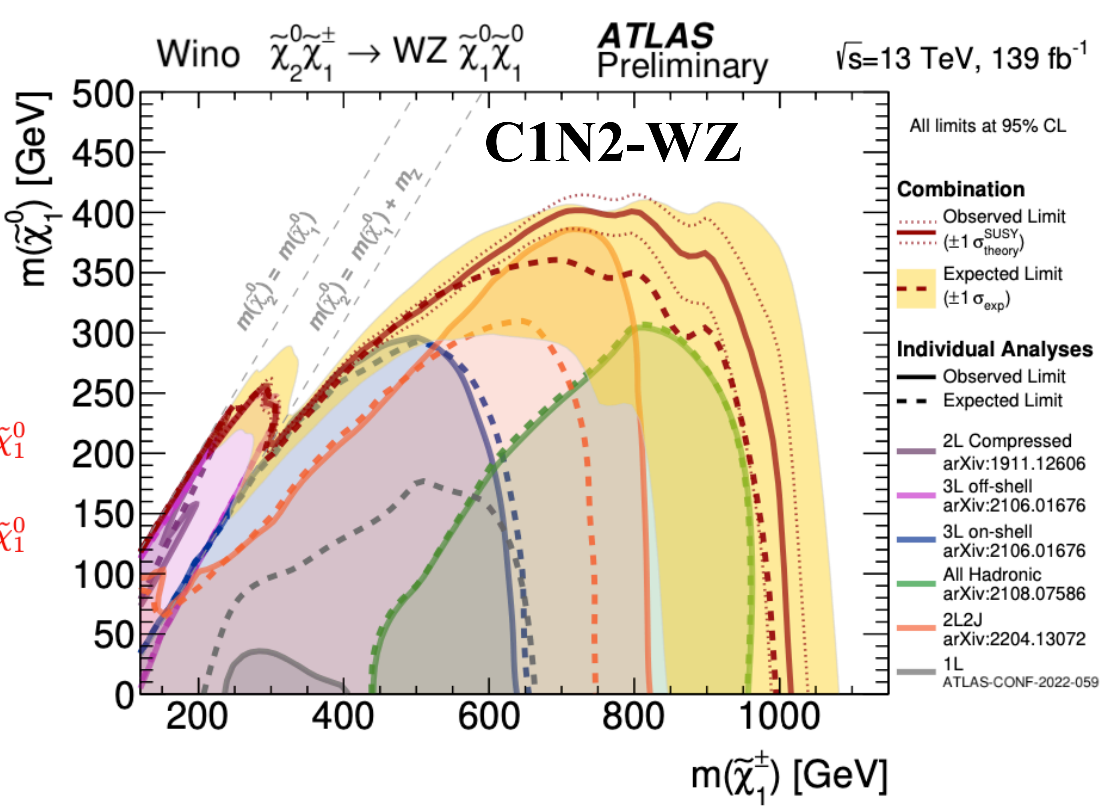
- **Decay via W/Z**

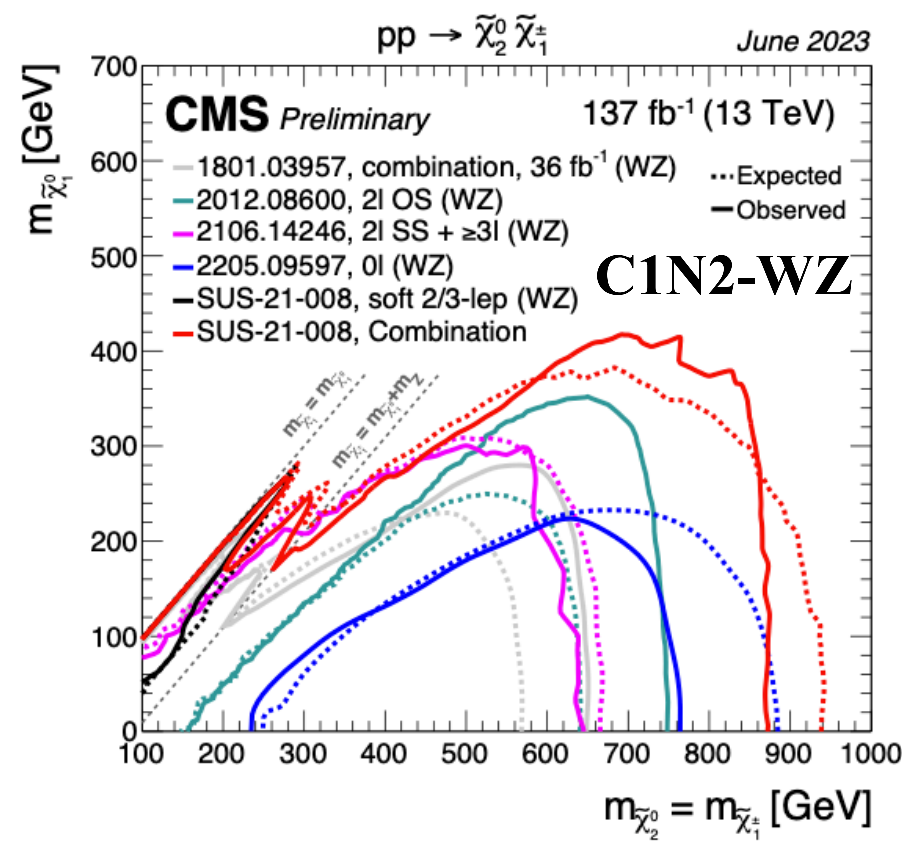




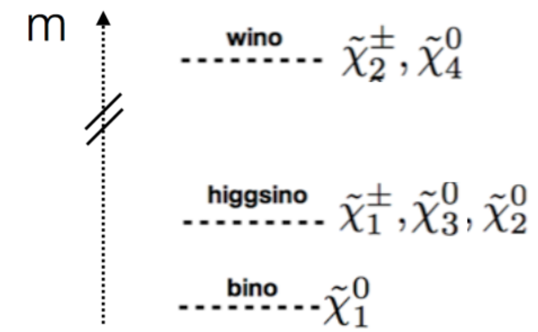
- **ATLAS only for *C1C1*, limit is excluded up to ~800 GeV for massless LSP; the new 1L channel has filled in the previous medium mass gap region!**
- **For *C1N2*, better sensitivity in ATLAS (~1 TeV) than in CMS (~900 GeV) for low mass LSPs; the off-shell region is well covered by compressed and SS channels!**



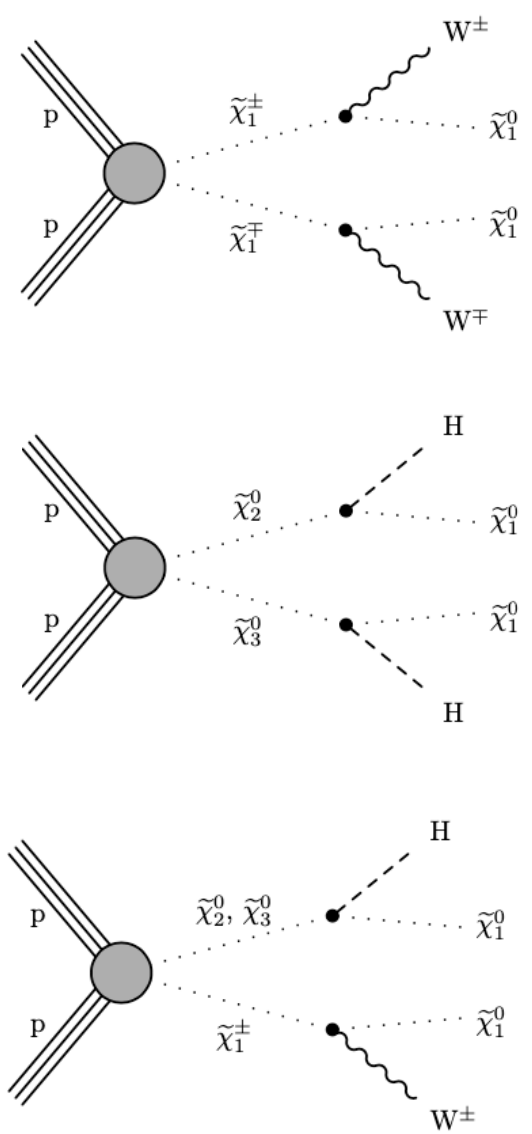


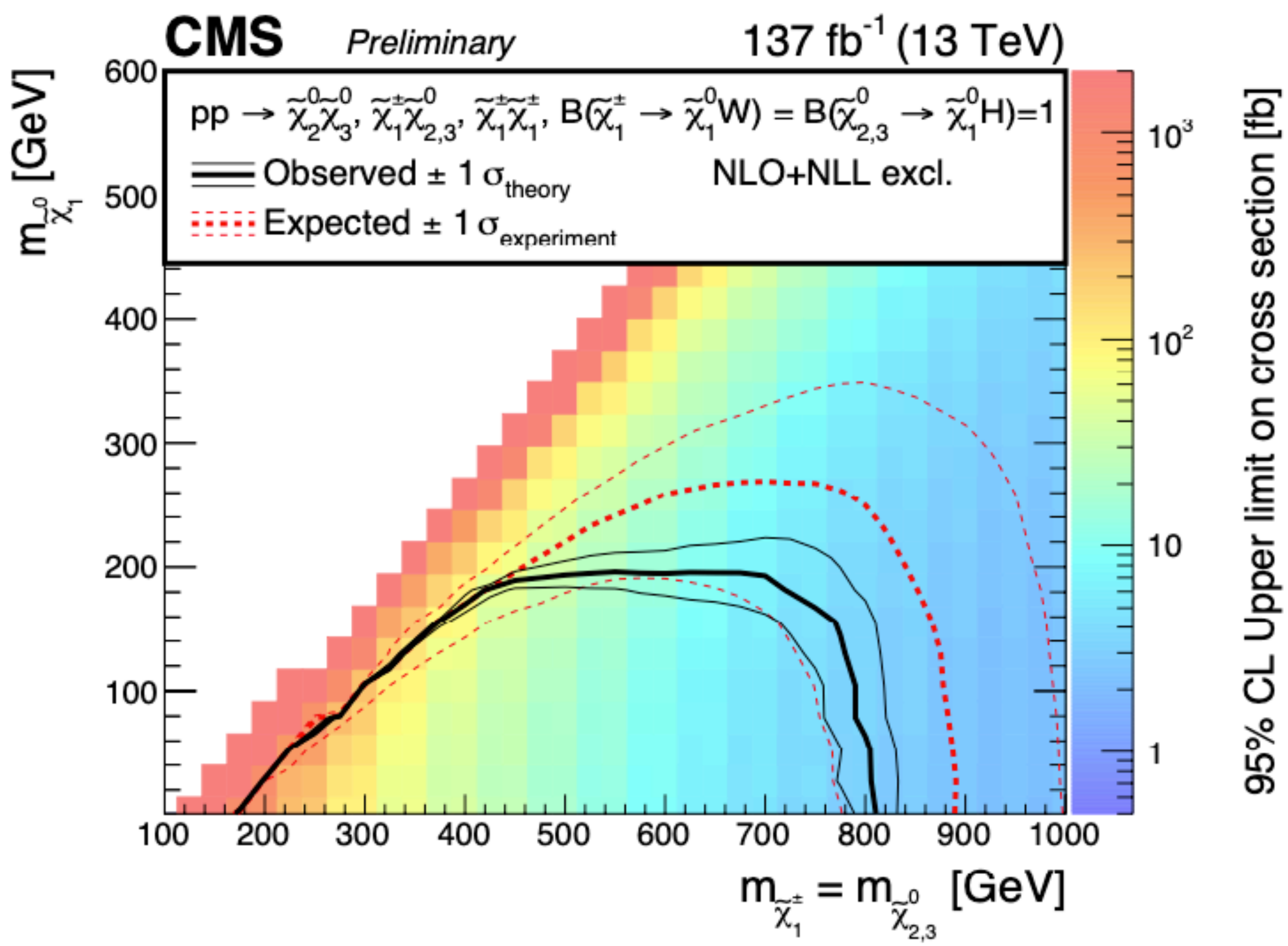


Higgsino-bino model

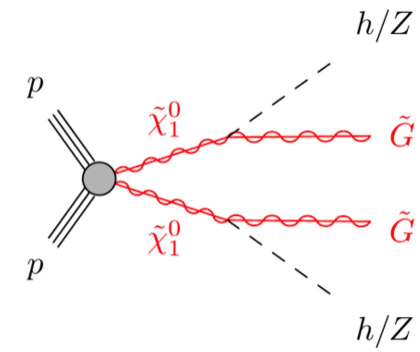


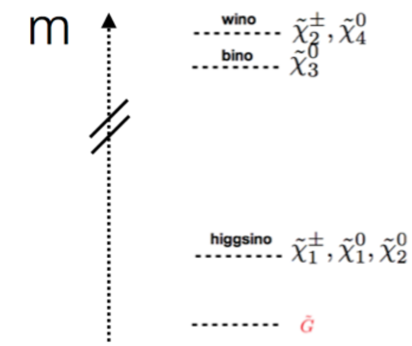
- **Mass degenerate higgsino-like N2/N3/C1 and Bino-like N1 as LSP; decay via W/H**
- **Only interpreted in CMS; weaker limits (~200-800 GeV For low LSP) than wino-bino**



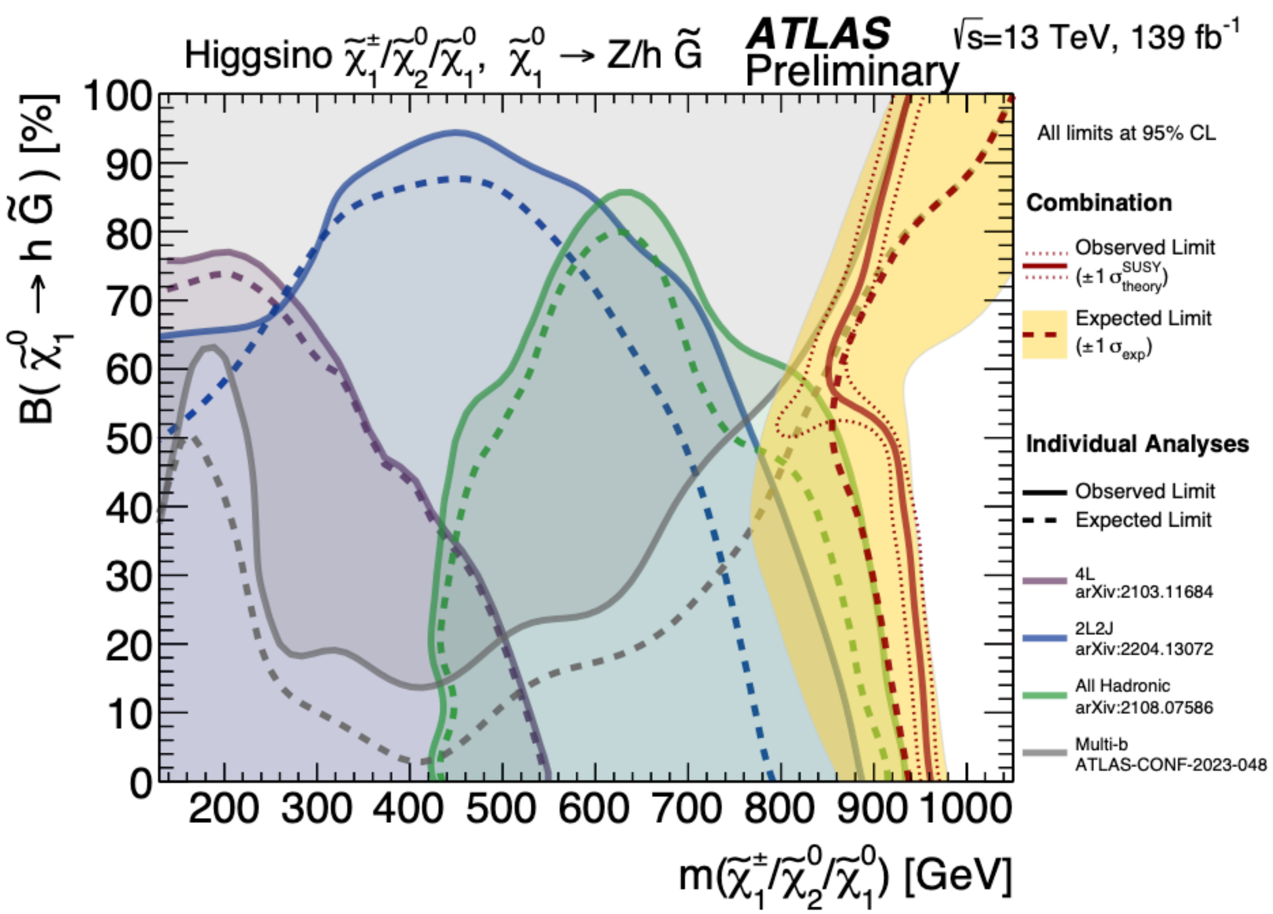


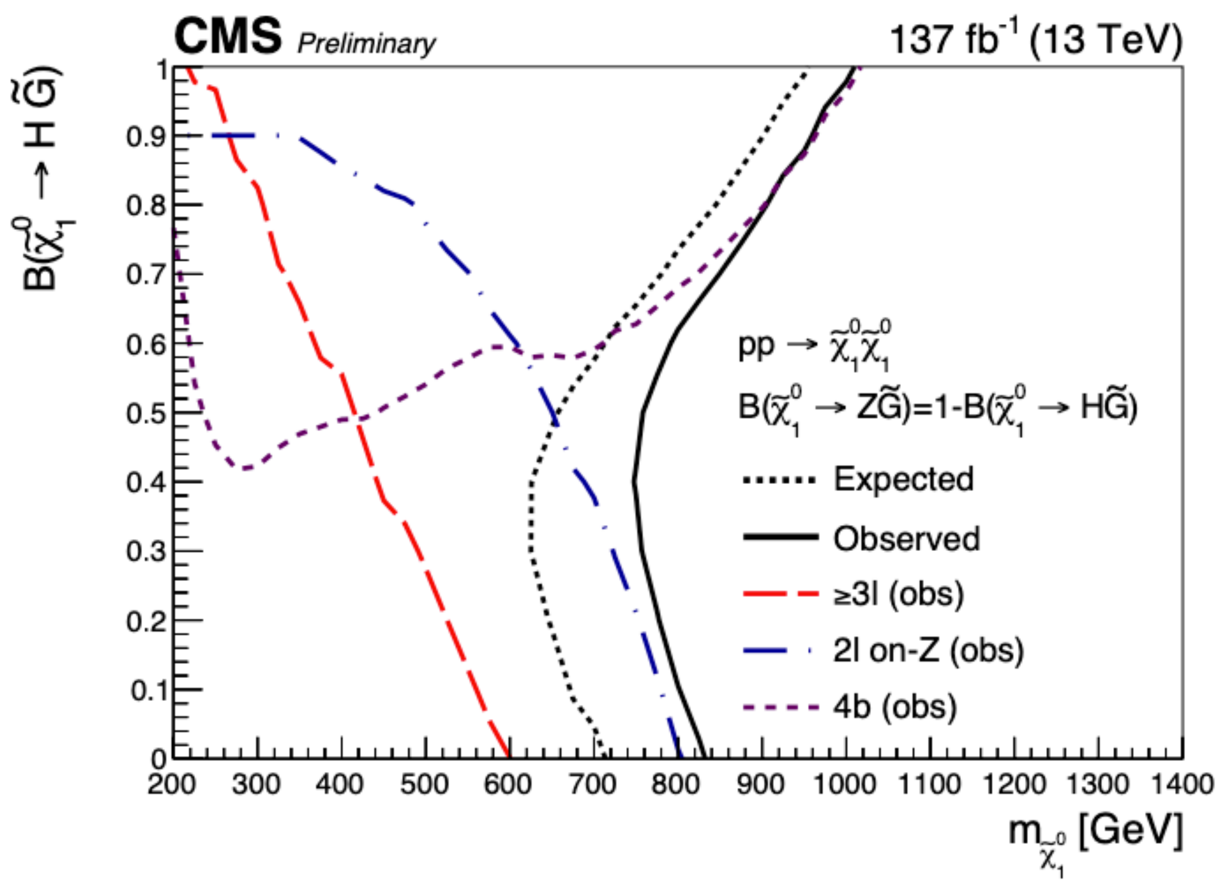
Higgsino model





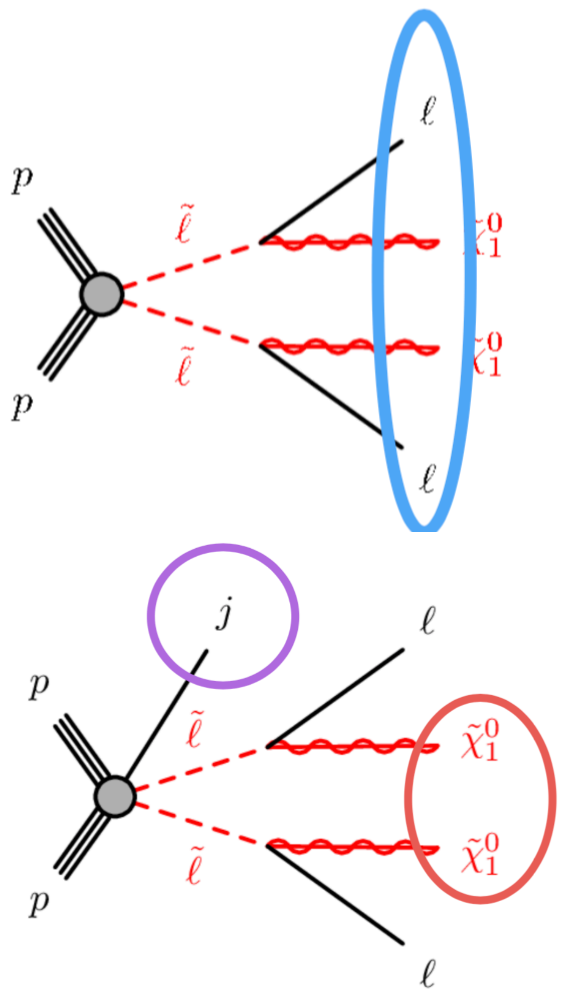
- **GGM: Higgsino-like NLSP; Gravitino as LSP; Decay via Z/H**



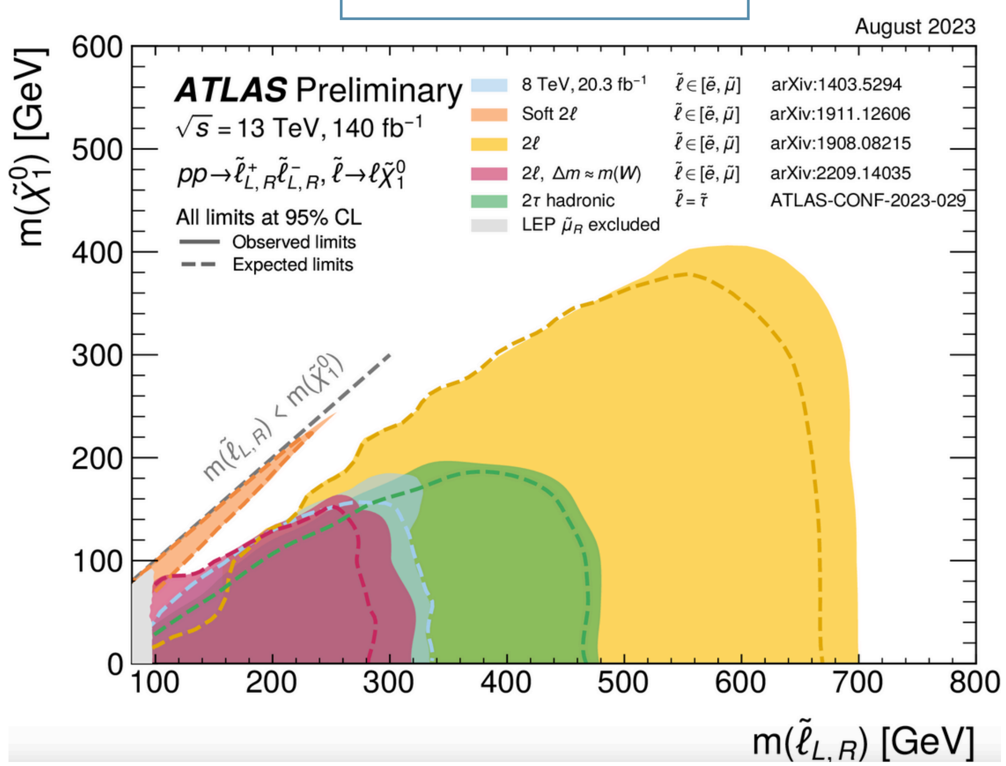


- **For Higgs dominant decay mode, multi-b channel wins**
- **For Z dominant decay mode, multi-lepton(3L/4L) impacts most in low mass region; allHad improves high mass region <— better in ATLAS (~960 GeV) than in CMS (~840 GeV) as allHad is not considered in the latter case**

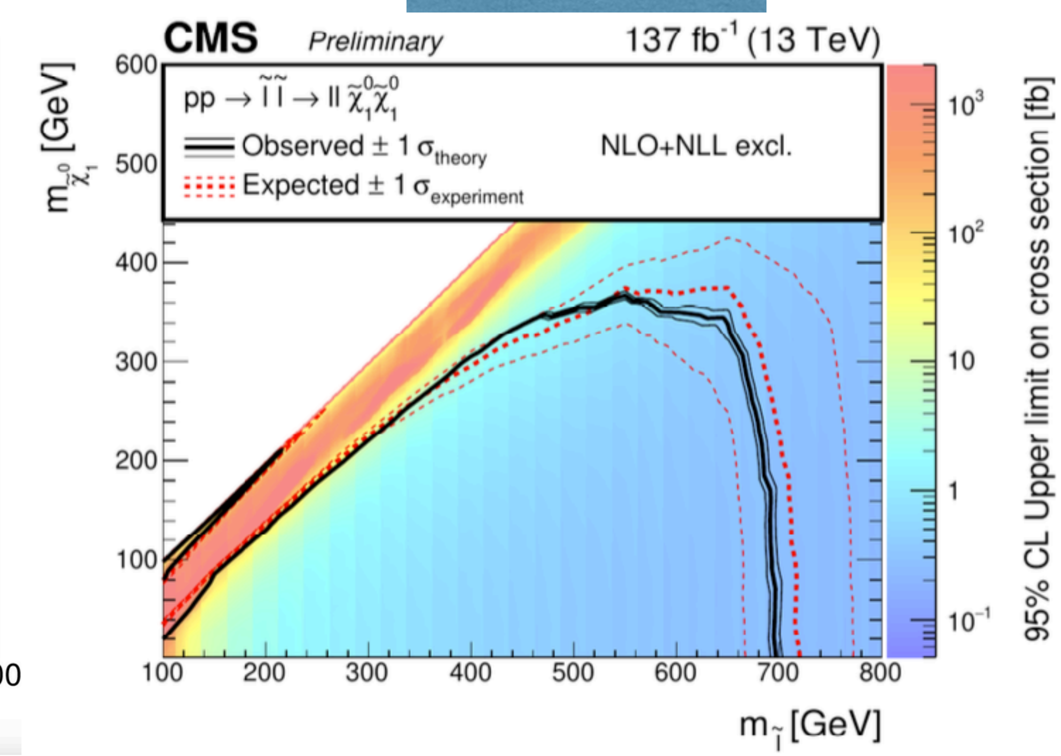
Slepton summary



NOT Combination



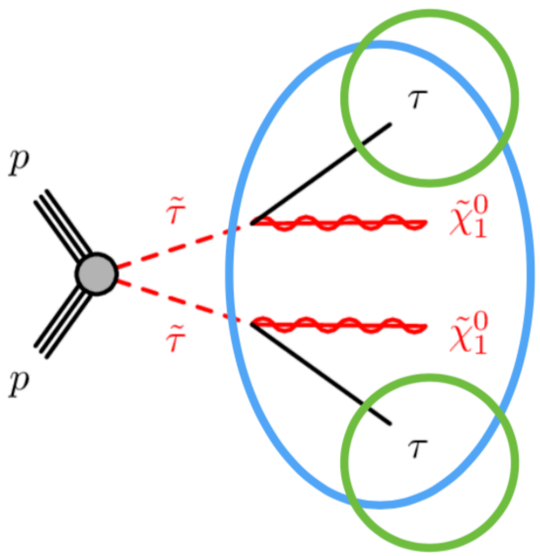
Combination



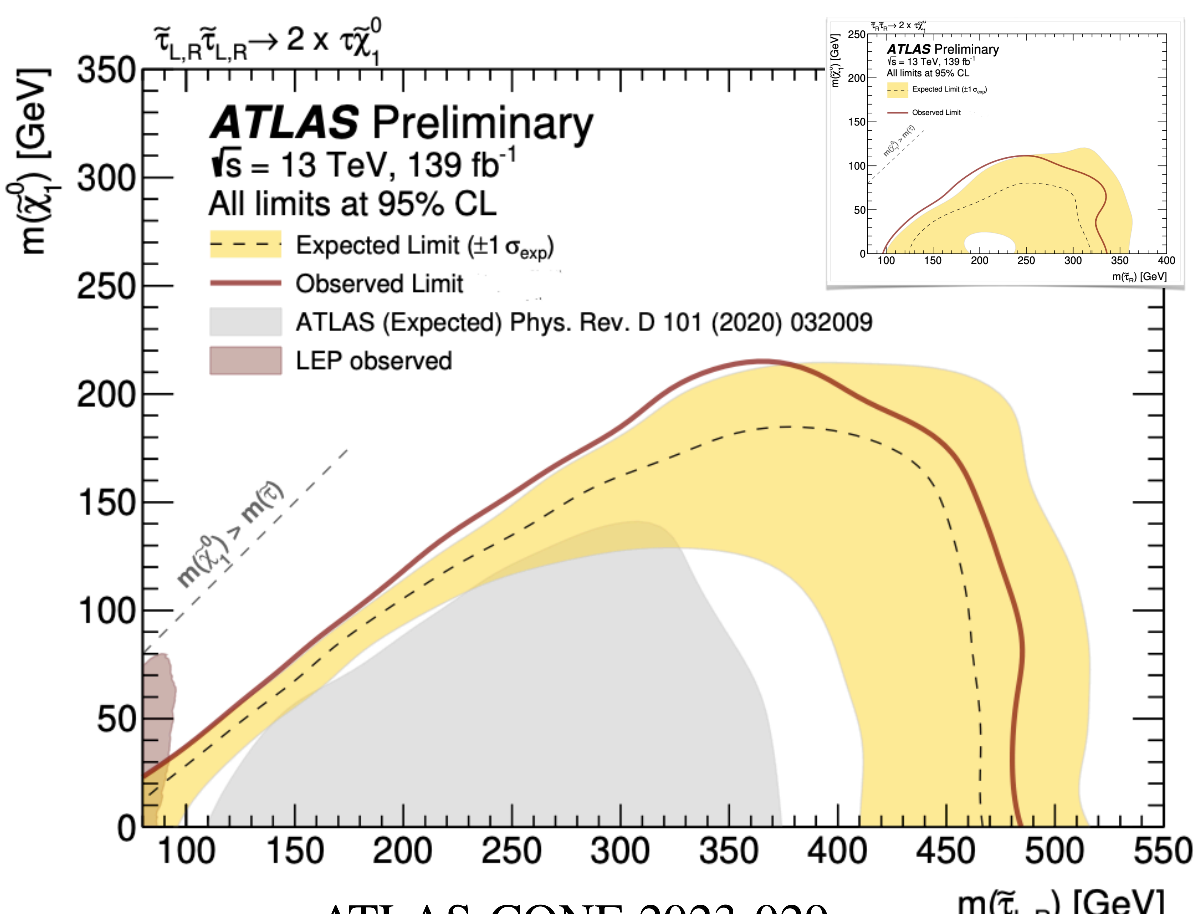
- Similar sensitivity reach in high mass; better coverage in diagonal region for ATLAS benefited from a new analysis targeting moderate mass splitting.

- **Search 1: Final states with 2 hard e/μ (pT>25GeV) —> target *high* mass region up to ~700 GeV!**
- **Search 2: Compressed analysis — 2 soft e/μ (pT_e>4.5GeV and pT_μ>3GeV) + ISR-jet —> target *small mass splitting* region!**
- **Search 3: ATLAS has released a new 2 moderate e/μ analysis only targeting the *moderate mass splitting* region to cover the gap!**

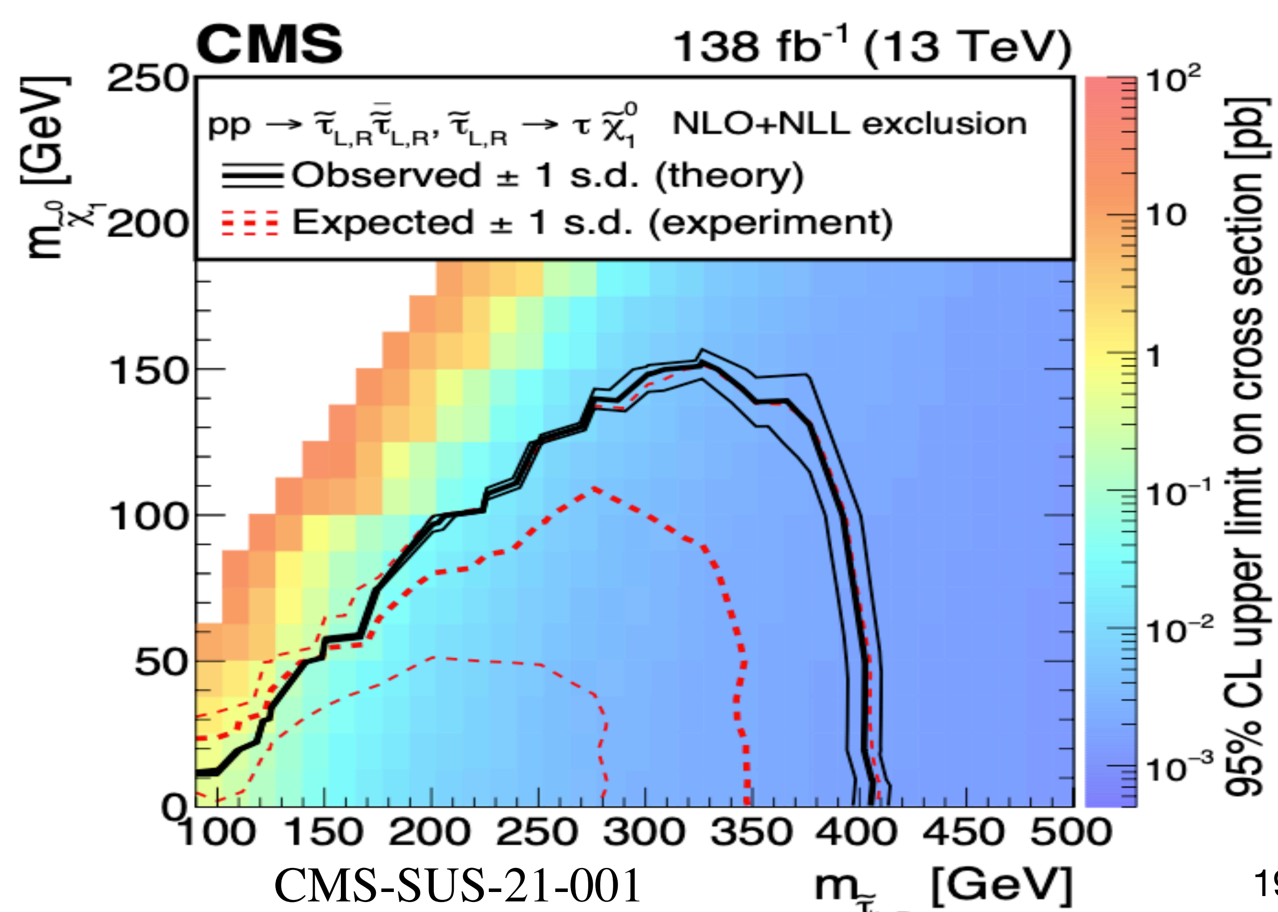
Stau summary



- **New limit on stau from ATLAS: Search for two hadronic tau final state!**
  - **Large improvement in both small mass splitting and high mass region: masses up to 480 GeV are excluded for massless $\tilde{\chi}_1^0$.**
  - **The first sensitivity to $\tilde{\tau}_R$ pair production scenarios.**
  - **Four BDTs are trained targeting different masses.**



ATLAS-CONF-2023-029



CMS-SUS-21-001

Analysis considered

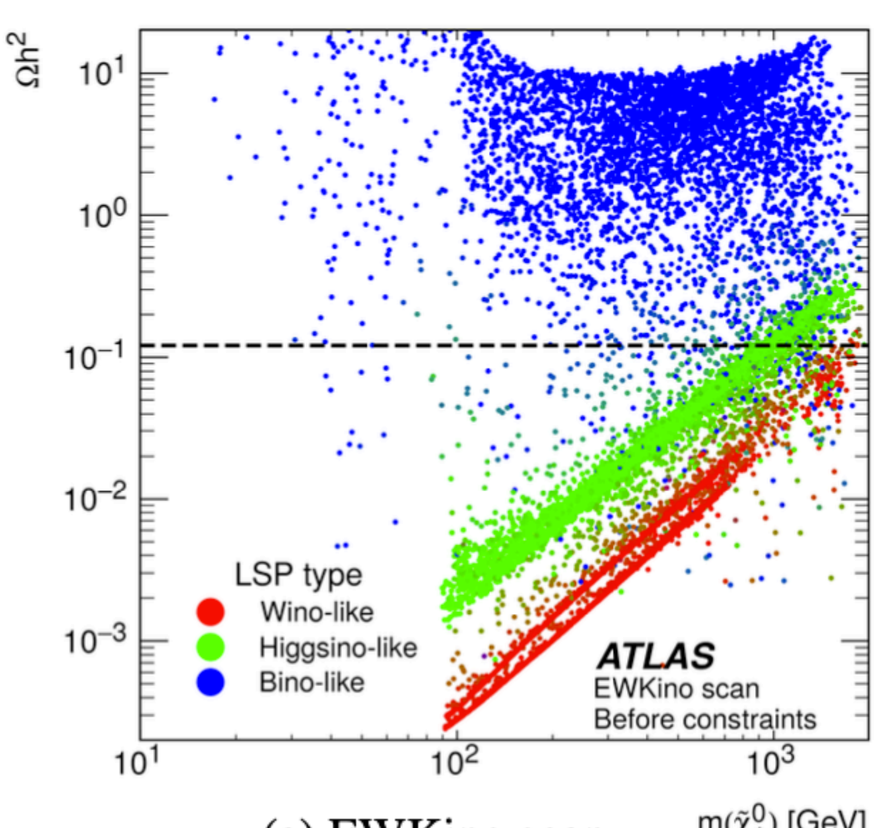
- FullHad [24]
- 1Lbb [15]
- 2L0J [19]
- 2L2J [25]
- 3L [23]
- 4L [22]
- Compressed [20]
- Disappearing-track [27]

pMSSM — NEW!

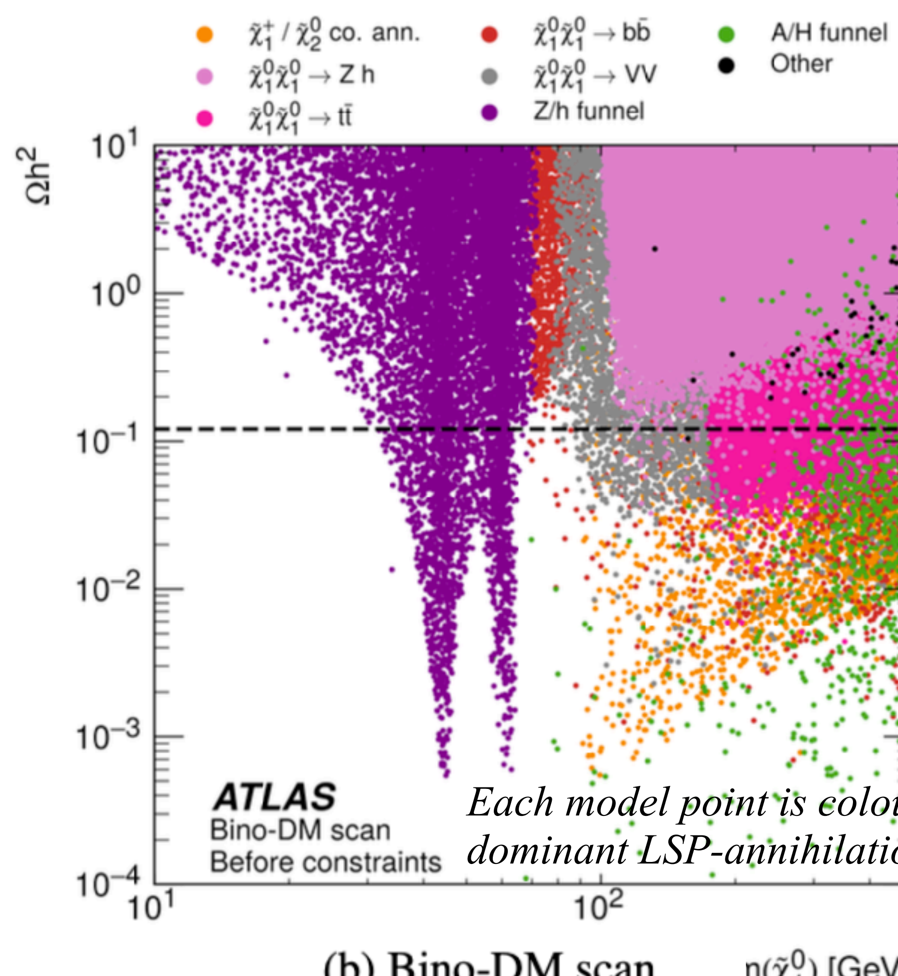
ATLAS-CONF-2023-055

pMSSM Parameter
$\tan\beta$
M_A
μ
M_1, M_2, M_3
A_t, A_b, A_τ
$M_{\tilde{q}}$, $M_{\tilde{u}_R}$, $M_{\tilde{d}_R}$, $M_{\tilde{l}}$, $M_{\tilde{e}_R}$
$M_{\tilde{Q}}$, $M_{\tilde{t}_R}$, $M_{\tilde{b}_R}$, $M_{\tilde{L}}$, $M_{\tilde{\tau}_R}$

- **Previous discussions rely on the *Simplified models*, here we want to discuss *pMSSM*!**
- **Interpretation in a phenomenological MSSM in a 19-dimensional parameter space**
  - **EWKino scan: general EWK production**
  - **Bino-like LSP mostly not survive DM relic density constraint**
  - **Bino-DM scan: allow enough stats. of bino-like LSP models (M1<500GeV) even with DM constraint**
  - **Interesting area: "Z/h funnel" & $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ co-annihilation**



(a) EWKino scan



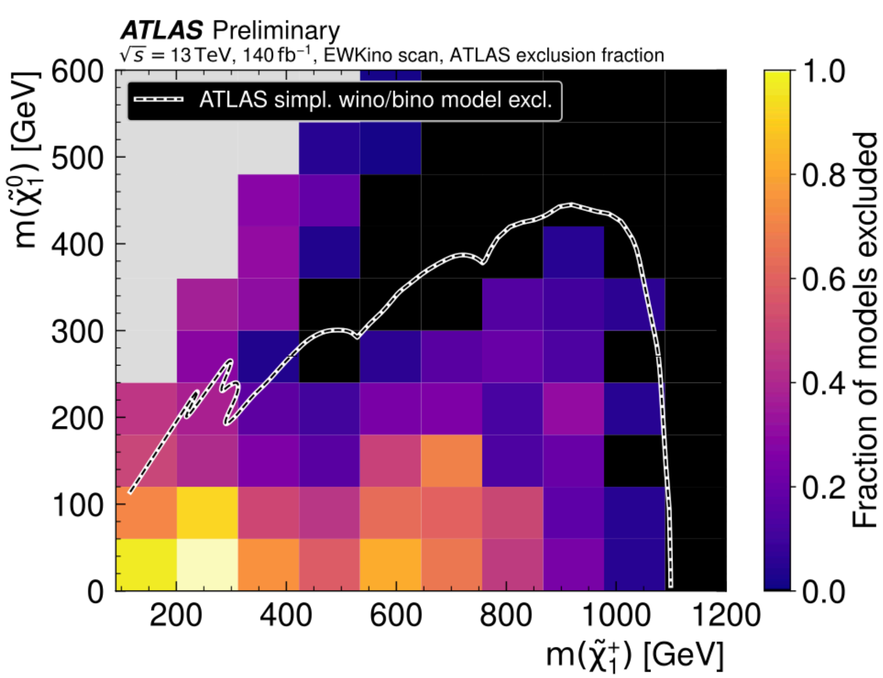
Each model point is coloured by the dominant LSP-annihilation mechanism

(b) Bino-DM scan

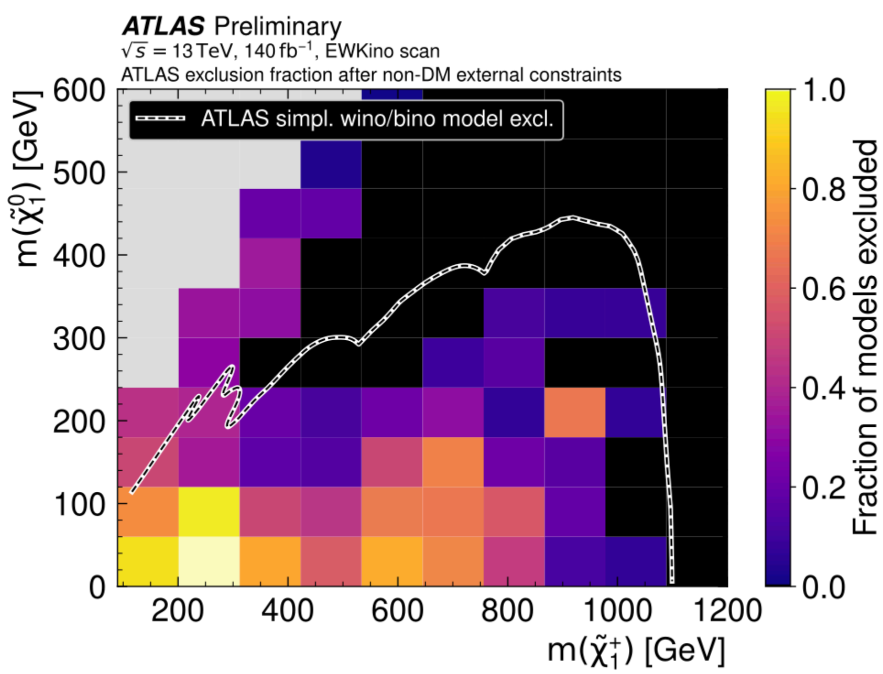
pMSSM

EWKino scan

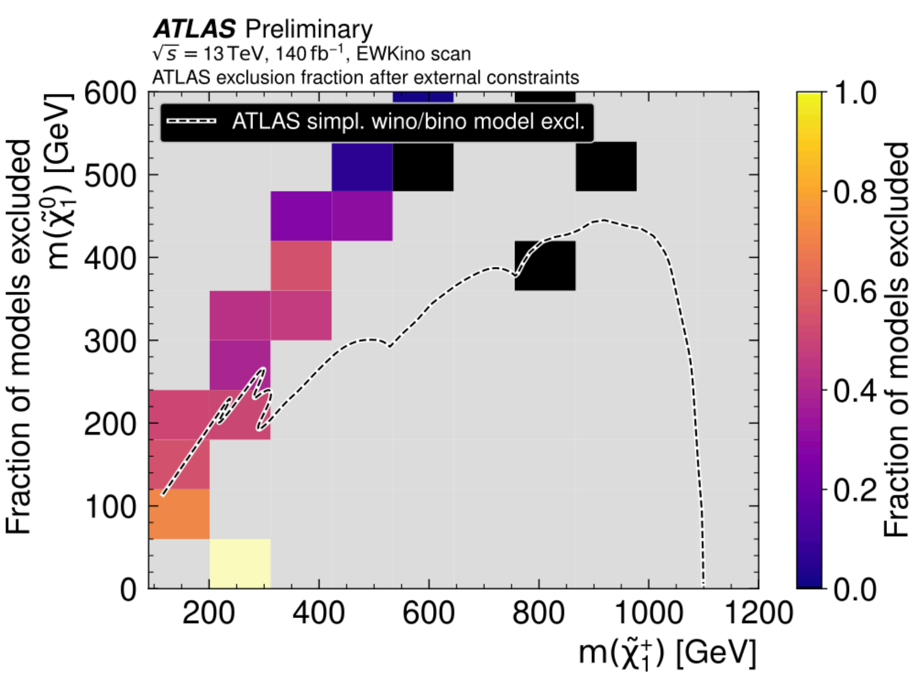
- **The fraction of models excluded by the ATLAS Run 2 electroweak searches**
- **Plots are overlaid with a contour indicating the exclusion for relevant simplified models**



(a) All models
No external constraints



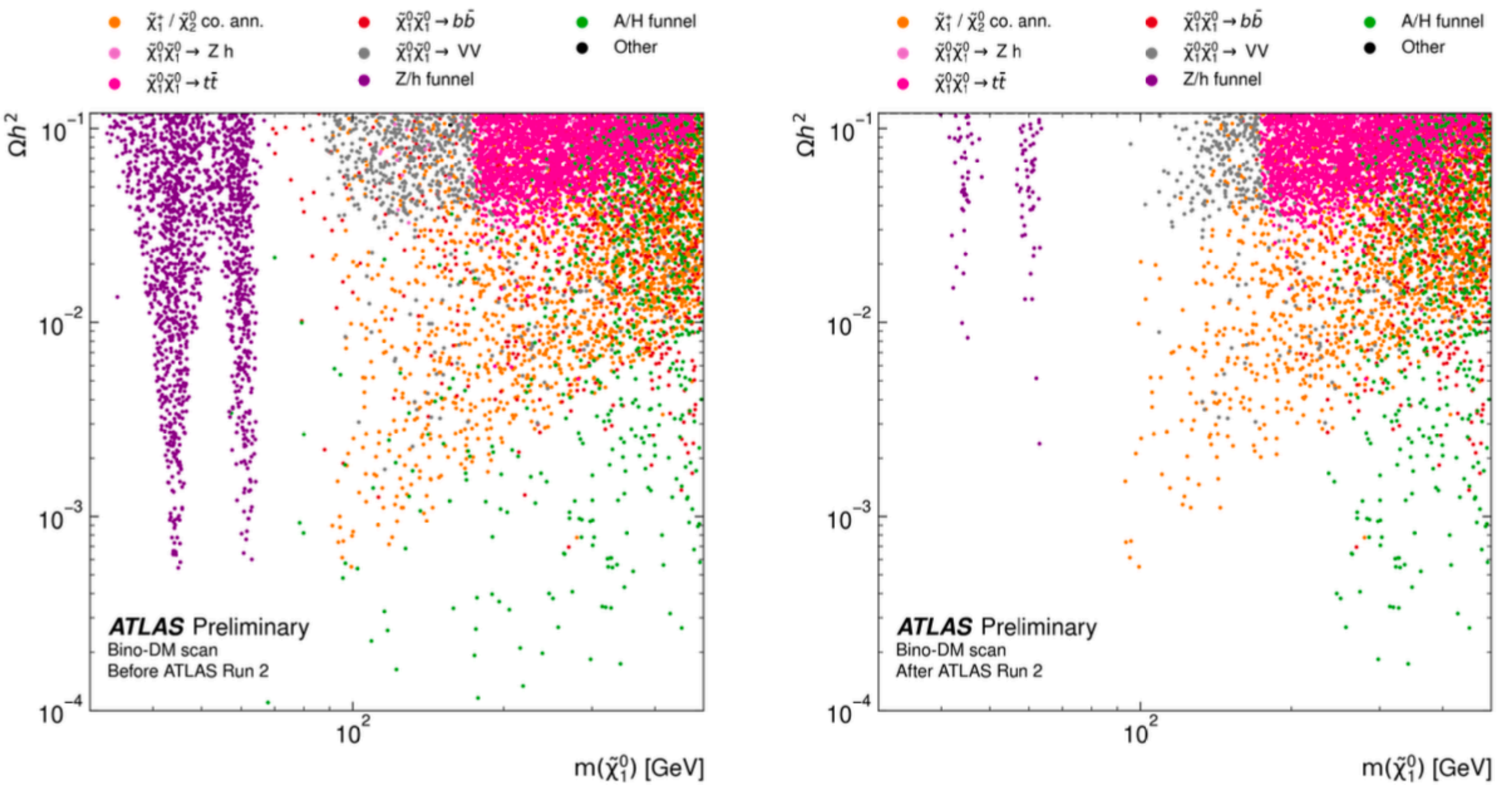
(c) Models passing non-DM external constraints
flavour, precision EWK constraints



(e) Models passing all external constraints
flavour, precision EWK & DM constraints

- **Most of the excluded models are inside the simplified model contour**
- **Although most inside contour models can be removed by the external constraints due to the DM relic density requirement which suppresses bino-LSP models**
- **A majority of the remaining models lying in the diagonal with small mass splittings**

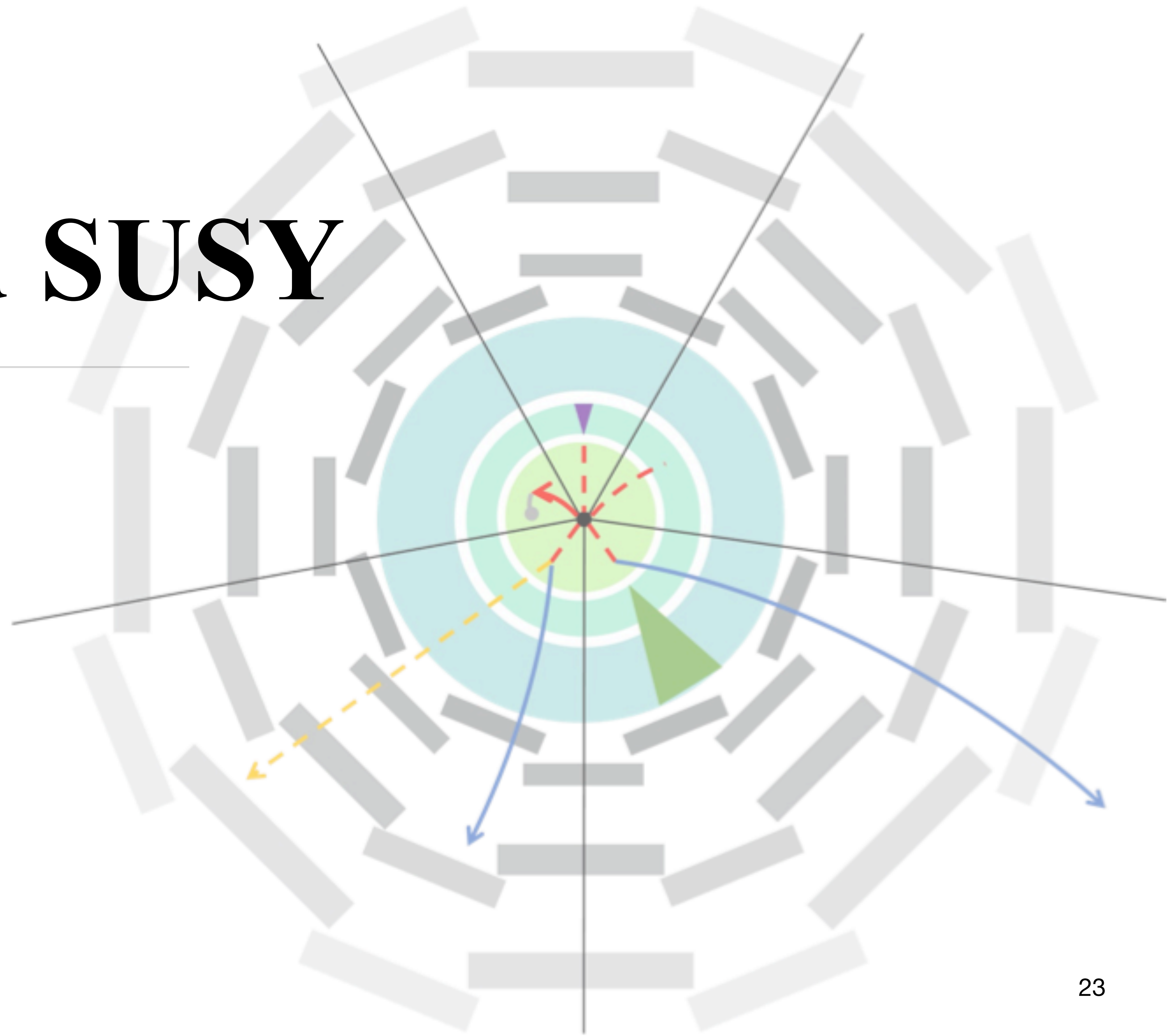
pMSSM



(a) All models (b) Models not excluded by ATLAS

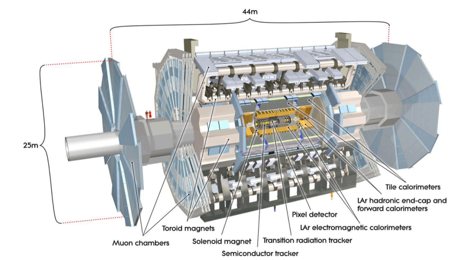
- The *Z*/*h* funnel regions are almost entirely excluded by ATLAS
- Models with $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ co-annihilation are still viable

Long-lived SUSY

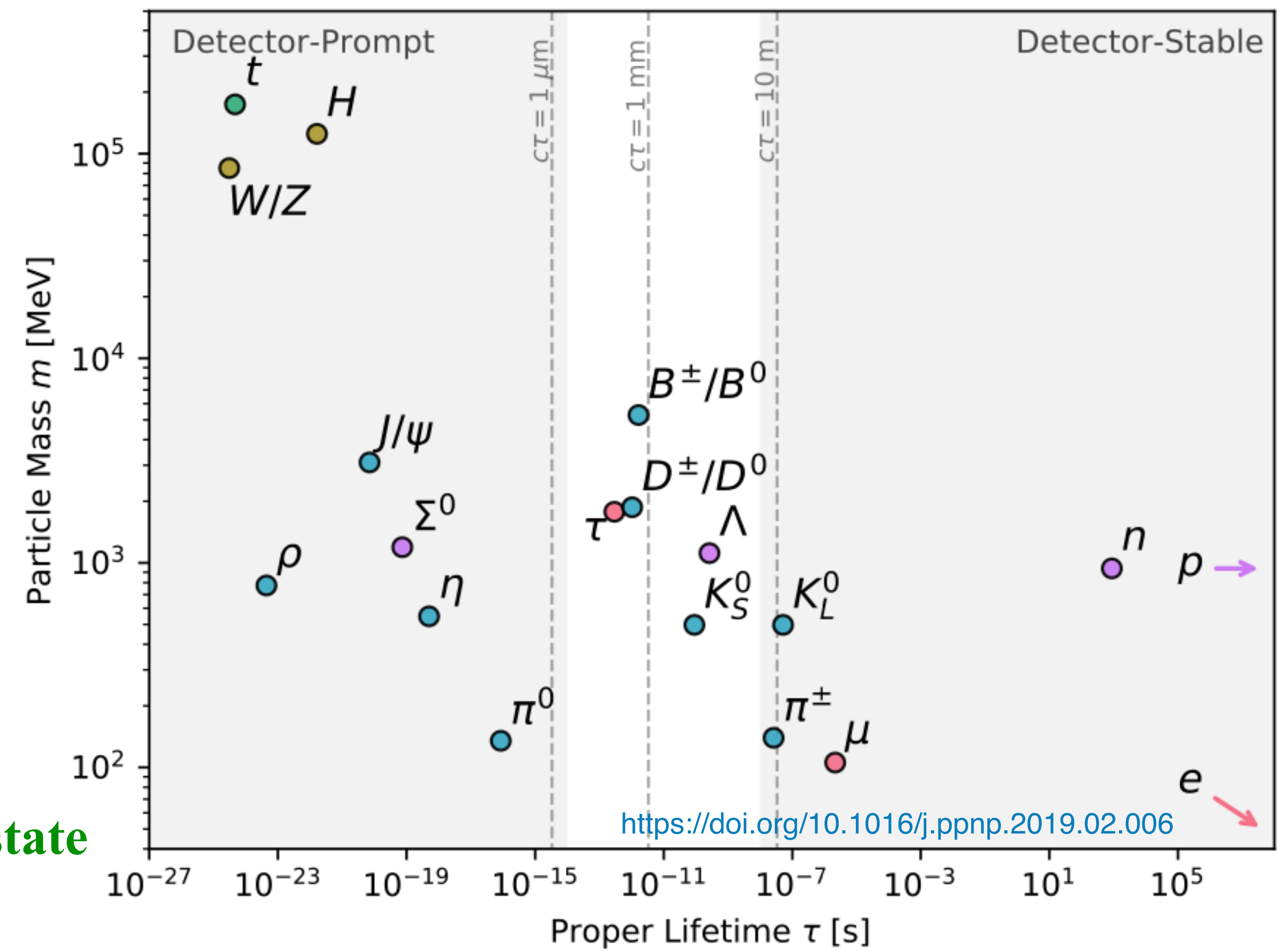


Why search for long lived particles?

Many SM particles are long-lived!

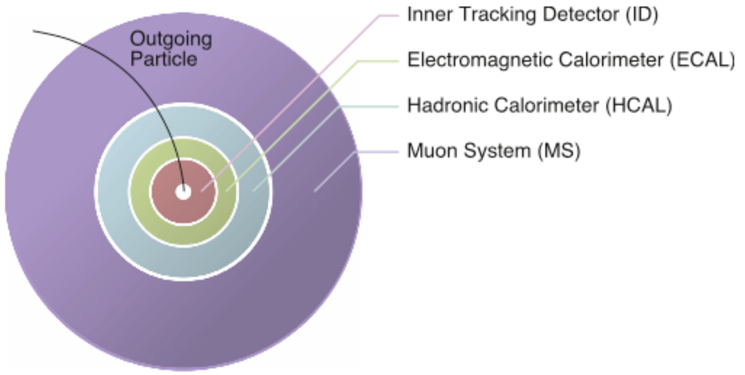


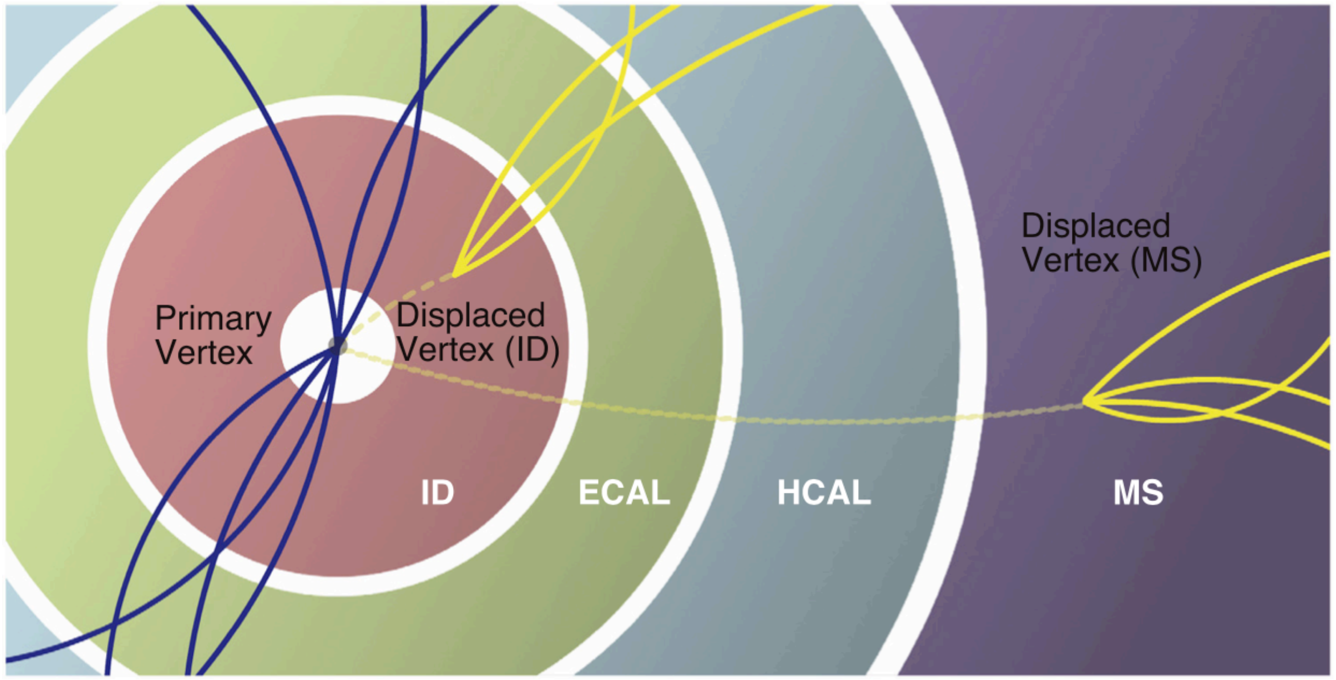
Decay suppression also plays in a variety of BSM scenarios.



LLP model essentials

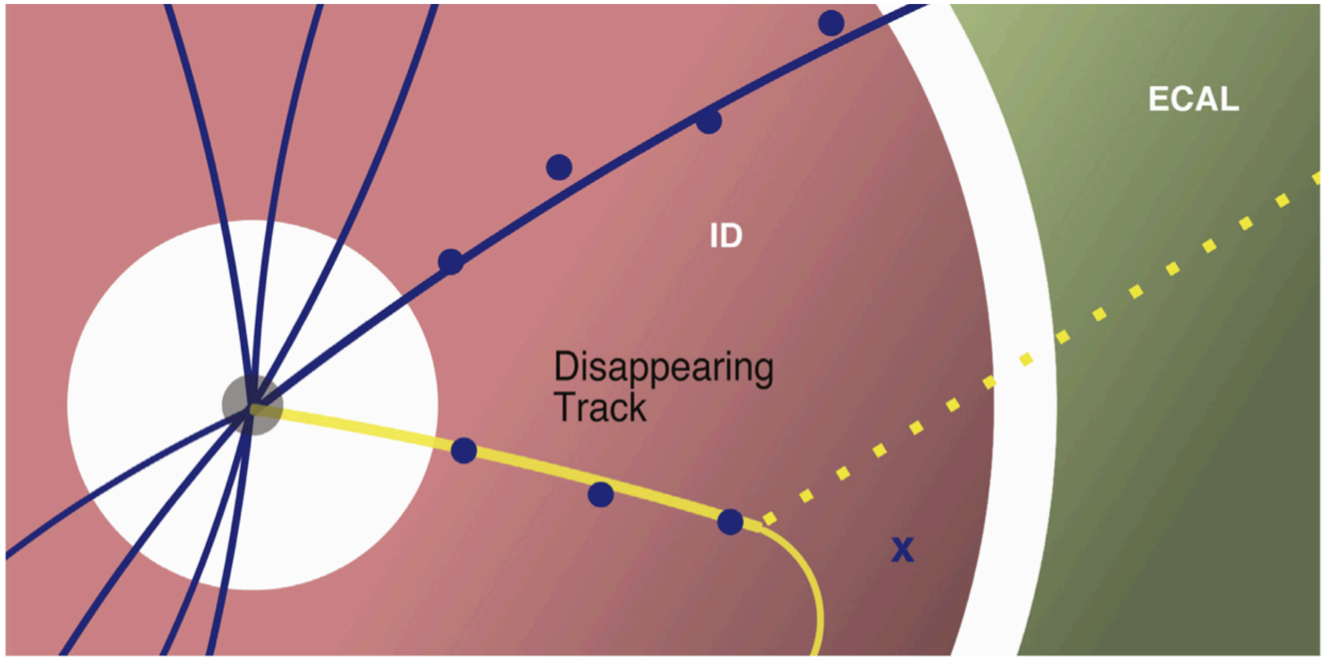
* (nearly) mass-degenerate
* small couplings
* highly virtual intermediate state

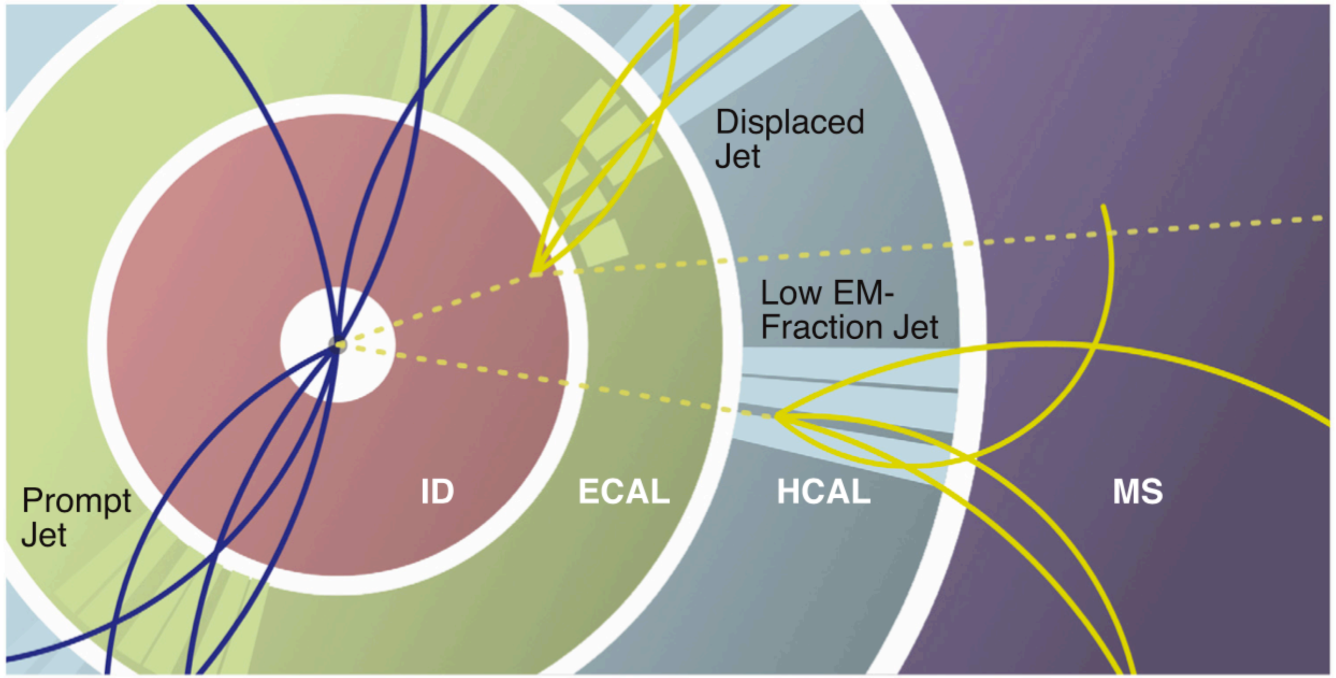


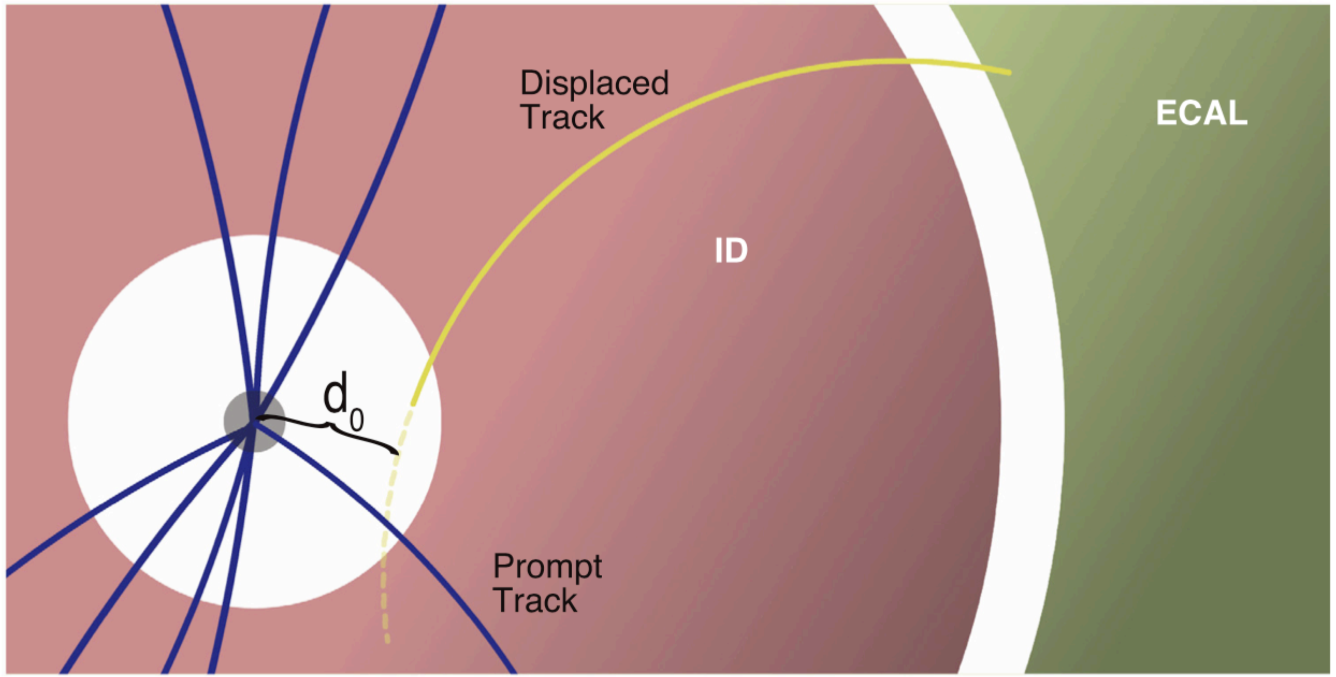


Detector signature

- Anomalous Ionization
- Delayed Detector Signals
- Disappearing Tracks
- Displaced Tracks
- Displaced Vertices
- …





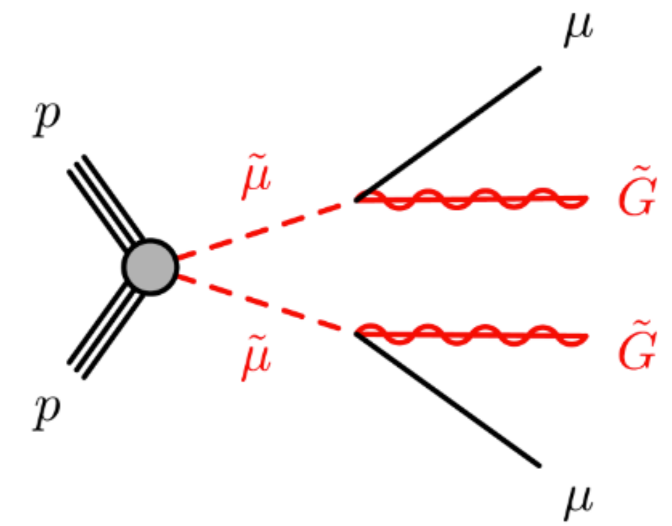


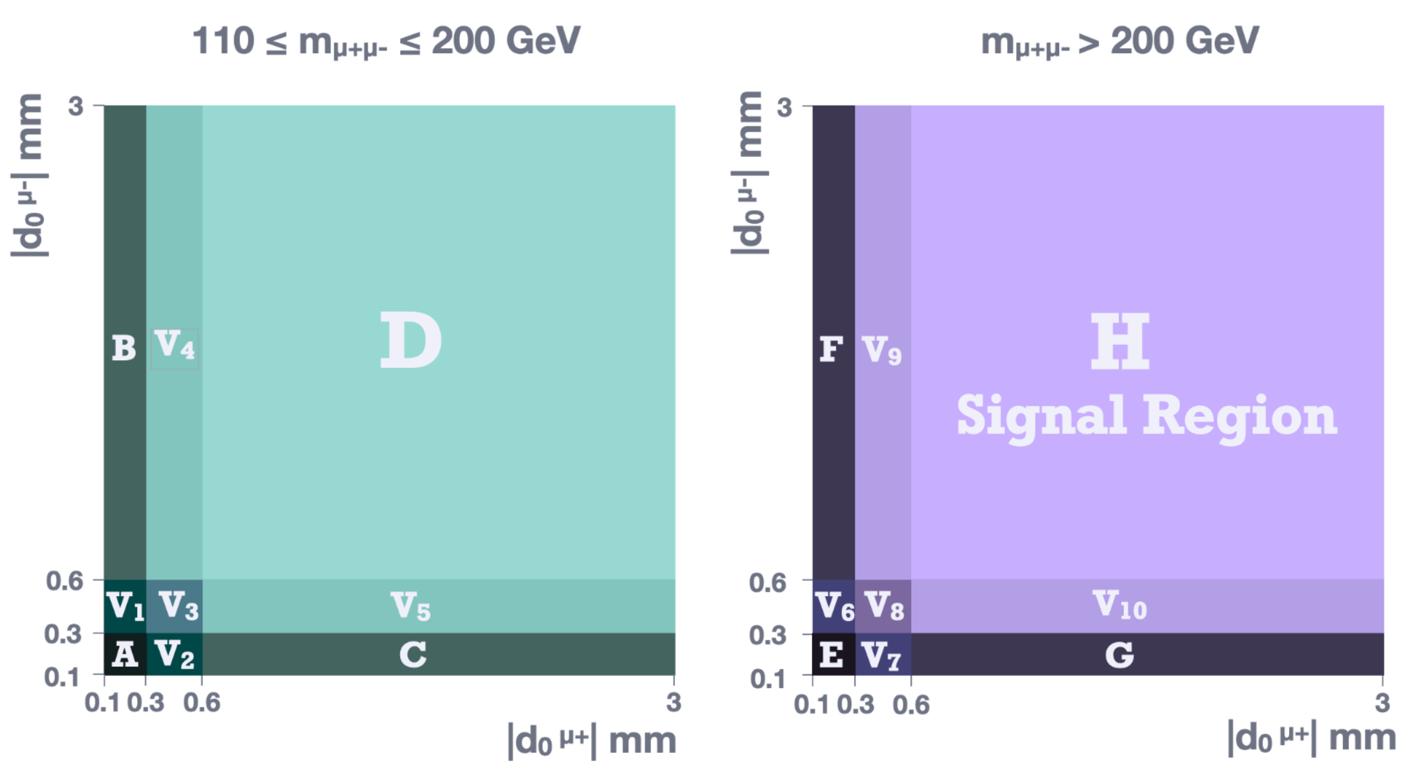
Micro-displaced muons

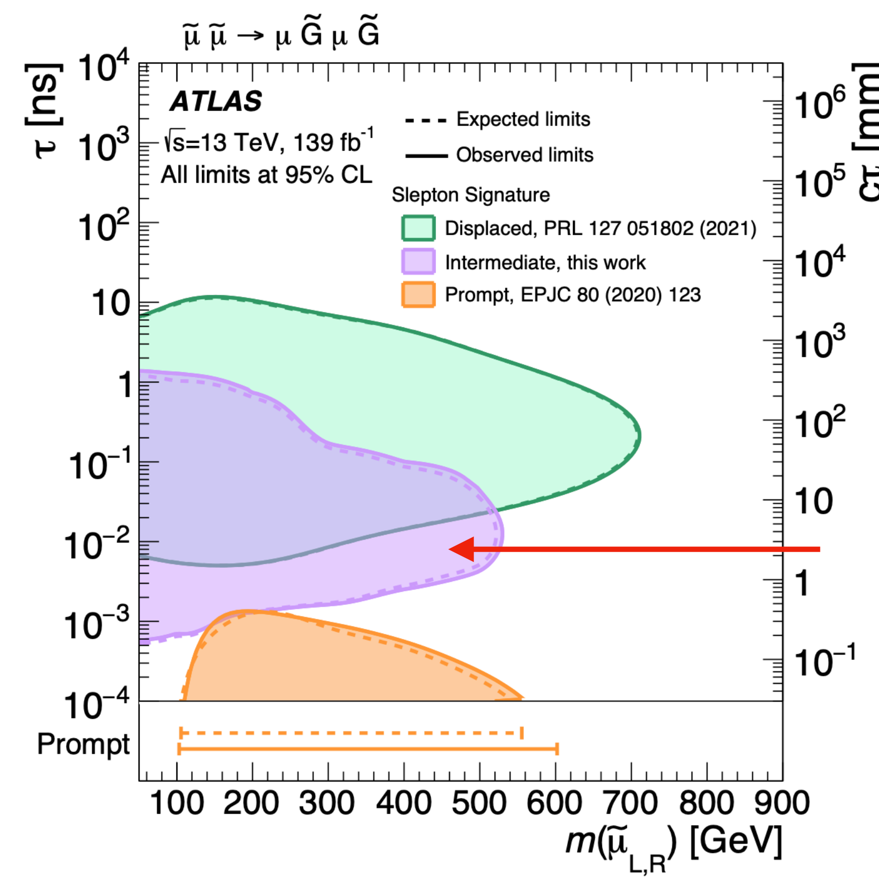
arXiv: 2305.02005

Pair produced smuons that live for short life time before decay to μ + Gravitino.

- **Muon with impact parameters in the *millimetre* range, targeting the medium displacement leptons: complementary to previous searches of large displacement and prompt smuons**
- **bb ➔ μμ is the dominant background, estimated with an extended ABCD data-driven method**
- **Smuon masses up to 520 GeV are excluded for a proper lifetime of 10 ps**





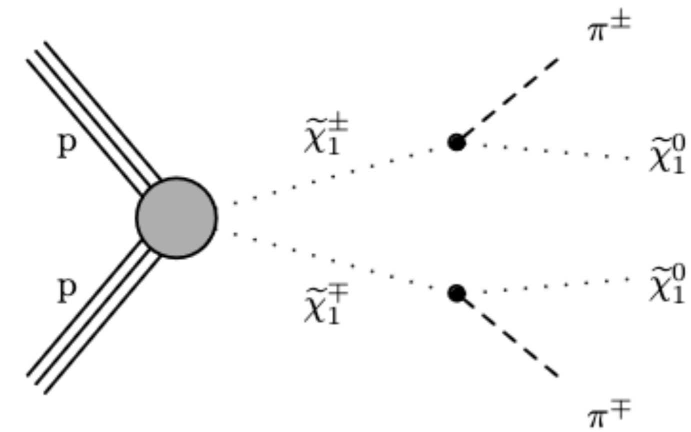


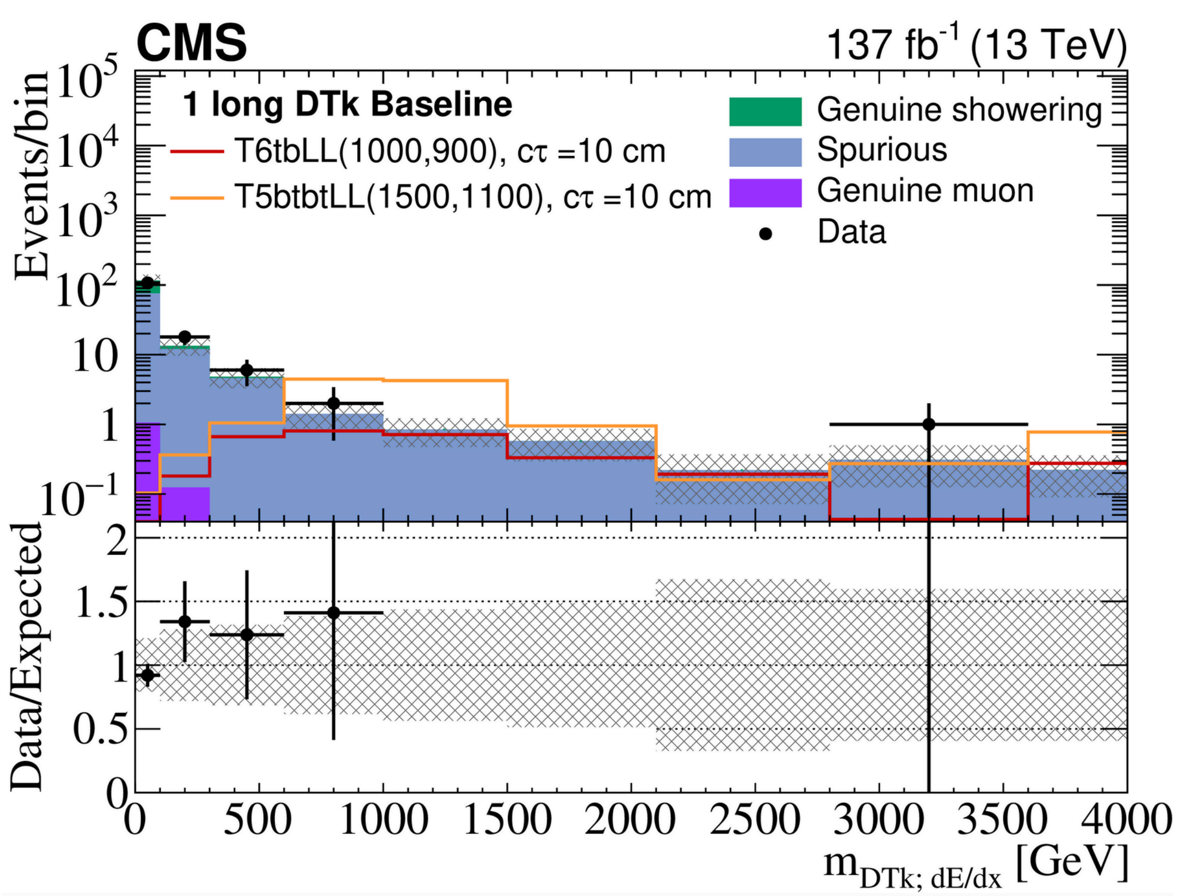
Disappearing track

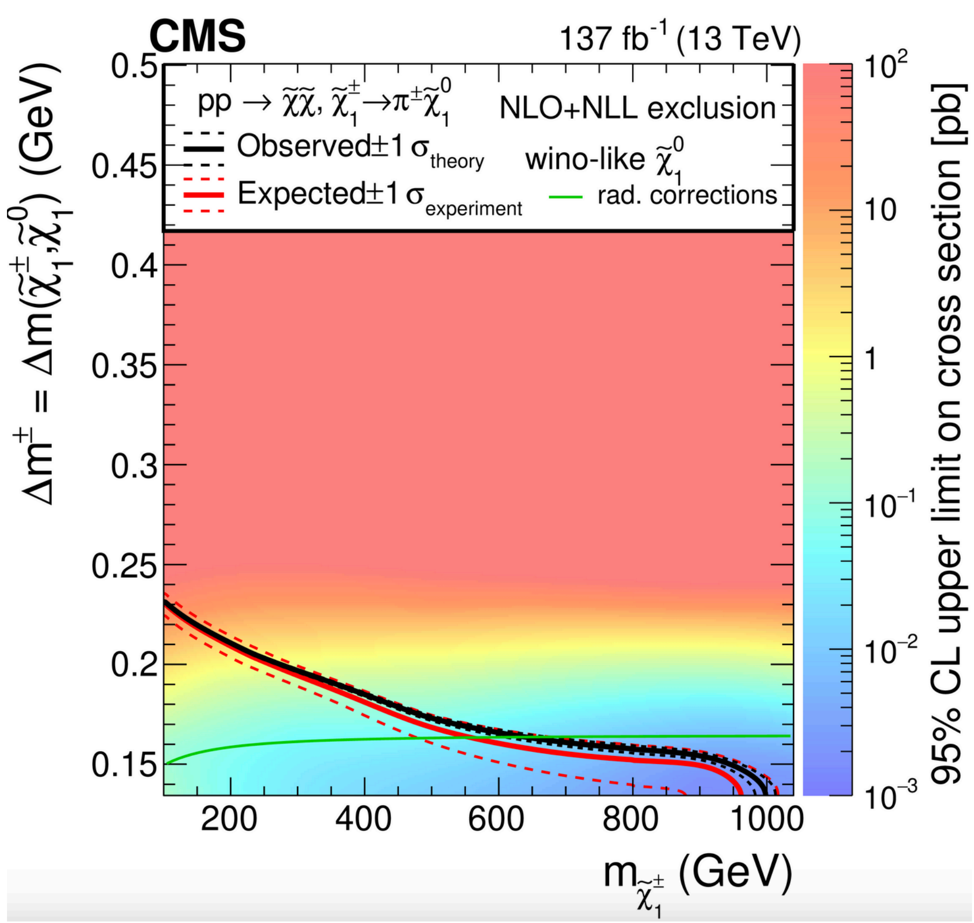
CMS-SUS-21-006

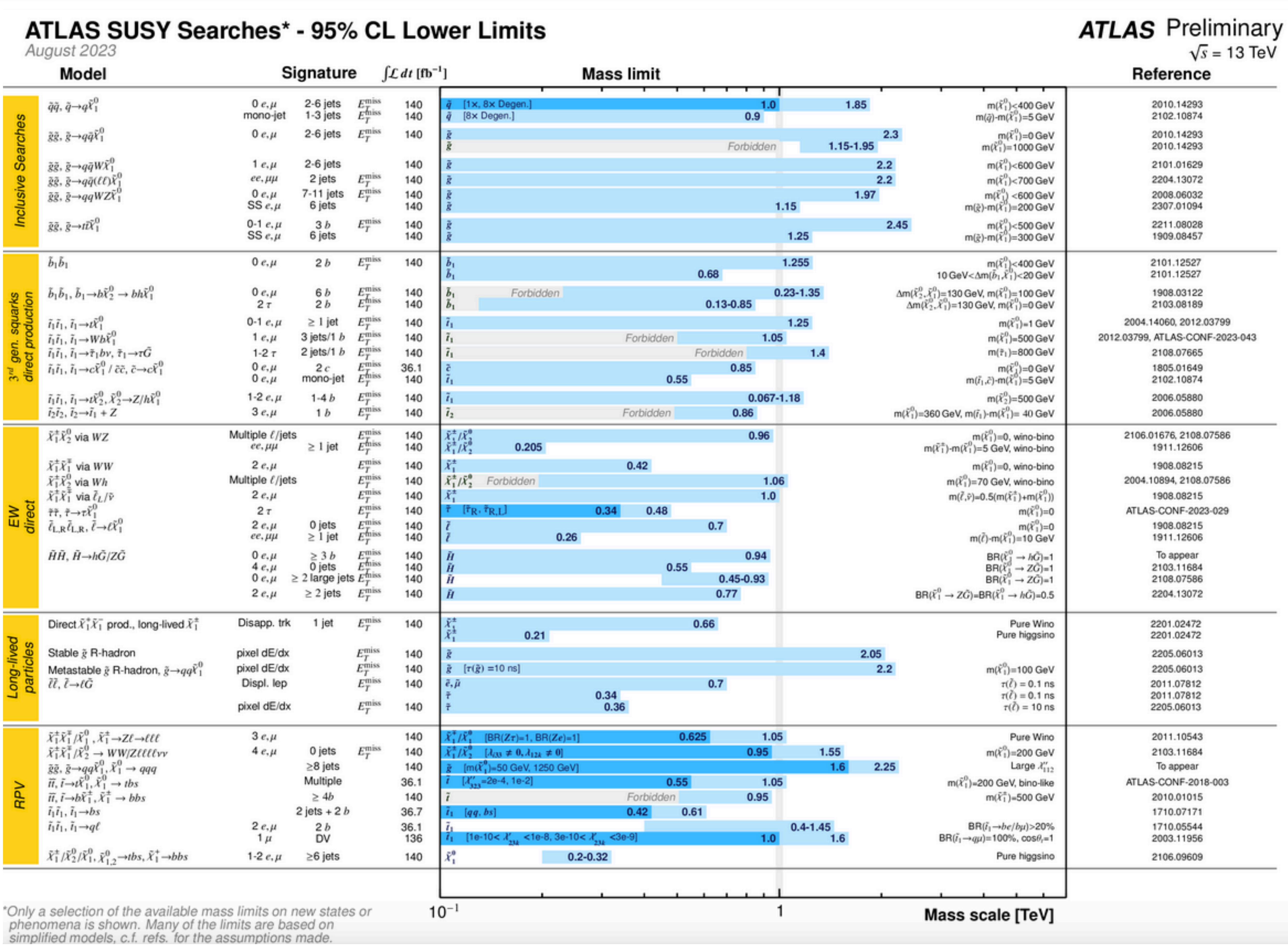
Search for charged, long-lived SUSY particles with one or more disappearing tracks.

- **For a pure wino-like or higgsino-like LSP, its chargino partner is nearly degenerate in mass.**
- **The dE/dx ionization energy loss in pixel for candidate tracks is sensitivity to charginos with a large mass.**
- **Similar study from ATLAS in** ***Eur. Phys. J. C 82 (2022) 606*****.**









ATLAS SUSY Searches* - 95% CL Lower Limits
August 2023
ATLAS Preliminary
√s = 13 TeV
Model | Signature | ∫L dt [fb⁻¹] | Mass limit | Reference
Inclusive Searches
q̃q̃, q̃→qχ̃⁰₁ | 0 e,μ 2-6 jets E_T^miss | 140 | q̃ [1×, 8× Degen.] 1.0 1.85 | m(χ̃⁰₁)<400 GeV | 2010.14293
mono-jet 1-3 jets E_T^miss | 140 | q̃ [8× Degen.] 0.9 | m(q̃)-m(χ̃⁰₁)=5 GeV | 2102.10874
g̃g̃, g̃→qq̄χ̃⁰₁ | 0 e,μ 2-6 jets E_T^miss | 140 | g̃ 2.3 | m(χ̃⁰₁)=0 GeV | 2010.14293
g̃ Forbidden 1.15-1.95 | m(χ̃⁰₁)=1000 GeV | 2010.14293
g̃g̃, g̃→qq̄Wχ̃⁰₁ | 1 e,μ 2-6 jets | 140 | g̃ 2.2 | m(χ̃⁰₁)<600 GeV | 2101.01629
g̃g̃, g̃→qq̄(ℓℓ)χ̃⁰₁ | ee,μμ 2 jets E_T^miss | 140 | g̃ 2.2 | m(χ̃⁰₁)<700 GeV | 2204.13072
g̃g̃, g̃→qqWZχ̃⁰₁ | 0 e,μ 7-11 jets E_T^miss | 140 | g̃ 1.97 | m(χ̃⁰₁)<600 GeV | 2008.06032
SS e,μ 6 jets | 140 | g̃ 1.15 | m(g̃)-m(χ̃⁰₁)=200 GeV | 2307.01094
g̃g̃, g̃→tt̄χ̃⁰₁ | 0-1 e,μ 3 b E_T^miss | 140 | g̃ 2.45 | m(χ̃⁰₁)<500 GeV | 2211.08028
SS e,μ 6 jets | 140 | g̃ 1.25 | m(g̃)-m(χ̃⁰₁)=300 GeV | 1909.08457
3rd gen. squarks direct production
b̃₁b̃₁ | 0 e,μ 2 b E_T^miss | 140 | b̃₁ 1.255 | m(χ̃⁰₁)<400 GeV | 2101.12527
b̃₁ 0.68 | 10 GeV<Δm(b̃₁,χ̃⁰₁)<20 GeV | 2101.12527
b̃₁b̃₁, b̃₁→bχ̃⁰₂→bhχ̃⁰₁ | 0 e,μ 6 b E_T^miss | 140 | b̃₁ Forbidden 0.23-1.35 | Δm(χ̃⁰₂,χ̃⁰₁)=130 GeV, m(χ̃⁰₁)=100 GeV | 1908.03122
2 τ 2 b E_T^miss | 140 | b̃₁ 0.13-0.85 | Δm(χ̃⁰₂,χ̃⁰₁)=130 GeV, m(χ̃⁰₁)=0 GeV | 2103.08189
t̃₁t̃₁, t̃₁→tχ̃⁰₁ | 0-1 e,μ ≥ 1 jet E_T^miss | 140 | t̃₁ 1.25 | m(χ̃⁰₁)=1 GeV | 2004.14060, 2012.03799
t̃₁t̃₁, t̃₁→Wbχ̃⁰₁ | 1 e,μ 3 jets/1 b E_T^miss | 140 | t̃₁ Forbidden 1.05 | m(χ̃⁰₁)=500 GeV | 2012.03799, ATLAS-CONF-2023-043
t̃₁t̃₁, t̃₁→τ̃₁bν, τ̃₁→τG̃ | 1-2 τ 2 jets/1 b E_T^miss | 140 | t̃₁ Forbidden 1.4 | m(τ̃₁)=800 GeV | 2108.07665
t̃₁t̃₁, t̃₁→cχ̃⁰₁ / c̃c̃, c̃→cχ̃⁰₁ | 0 e,μ 2 c E_T^miss | 36.1 | c̃ 0.85 | m(χ̃⁰₁)=0 GeV | 1805.01649
0 e,μ mono-jet E_T^miss | 140 | t̃₁ 0.55 | m(t̃₁,c̃)-m(χ̃⁰₁)=5 GeV | 2102.10874
t̃₁t̃₁, t̃₁→tχ̃⁰₂, χ̃⁰₂→Z/hχ̃⁰₁ | 1-2 e,μ 1-4 b E_T^miss | 140 | t̃₁ 0.067-1.18 | m(χ̃⁰₂)=500 GeV | 2006.05880
t̃₂t̃₂, t̃₂→t̃₁ + Z | 3 e,μ 1 b E_T^miss | 140 | t̃₂ Forbidden 0.86 | m(χ̃⁰₁)=360 GeV, m(t̃₁)-m(χ̃⁰₁)= 40 GeV | 2006.05880
EW direct
χ̃±₁χ̃⁰₂ via WZ | Multiple ℓ/jets E_T^miss | 140 | χ̃±₁/χ̃⁰₂ 0.96 | m(χ̃⁰₁)=0, wino-bino | 2106.01676, 2108.07586
ee,μμ ≥ 1 jet E_T^miss | 140 | χ̃±₁/χ̃⁰₂ 0.205 | m(χ̃±₁)-m(χ̃⁰₁)=5 GeV, wino-bino | 1911.12606
χ̃±₁χ̃∓₁ via WW | 2 e,μ E_T^miss | 140 | χ̃±₁ 0.42 | m(χ̃⁰₁)=0, wino-bino | 1908.08215
χ̃±₁χ̃⁰₂ via Wh | Multiple ℓ/jets E_T^miss | 140 | χ̃±₁/χ̃⁰₂ Forbidden 1.06 | m(χ̃⁰₁)=70 GeV, wino-bino | 2004.10894, 2108.07586
χ̃±₁χ̃∓₁ via ℓ̃_L/ν̃ | 2 e,μ E_T^miss | 140 | χ̃±₁ 1.0 | m(ℓ̃,ν̃)=0.5(m(χ̃±₁)+m(χ̃⁰₁)) | 1908.08215
τ̃τ̃, τ̃→τχ̃⁰₁ | 2 τ E_T^miss | 140 | τ̃ [τ̃R, τ̃R,L] 0.34 0.48 | m(χ̃⁰₁)=0 | ATLAS-CONF-2023-029
ℓ̃L,Rℓ̃L,R, ℓ̃→ℓχ̃⁰₁ | 2 e,μ 0 jets E_T^miss | 140 | ℓ̃ 0.7 | m(χ̃⁰₁)=0 | 1908.08215
ee,μμ ≥ 1 jet E_T^miss | 140 | ℓ̃ 0.26 | m(ℓ̃)-m(χ̃⁰₁)=10 GeV | 1911.12606
H̃H̃, H̃→hG̃/ZG̃ | 0 e,μ ≥ 3 b E_T^miss | 140 | H̃ 0.94 | BR(χ̃⁰₁ → hG̃)=1 | To appear
4 e,μ 0 jets E_T^miss | 140 | H̃ 0.55 | BR(χ̃⁰₁ → ZG̃)=1 | 2103.11684
0 e,μ ≥ 2 large jets E_T^miss | 140 | H̃ 0.45-0.93 | BR(χ̃⁰₁ → ZG̃)=1 | 2108.07586
2 e,μ ≥ 2 jets E_T^miss | 140 | H̃ 0.77 | BR(χ̃⁰₁ → ZG̃)=BR(χ̃⁰₁ → hG̃)=0.5 | 2204.13072
Long-lived particles
Direct χ̃⁺₁χ̃⁻₁ prod., long-lived χ̃±₁ | Disapp. trk 1 jet E_T^miss | 140 | χ̃±₁ 0.66 | Pure Wino | 2201.02472
χ̃±₁ 0.21 | Pure higgsino | 2201.02472
Stable g̃ R-hadron | pixel dE/dx E_T^miss | 140 | g̃ 2.05 | | 2205.06013
Metastable g̃ R-hadron, g̃→qqχ̃⁰₁ | pixel dE/dx E_T^miss | 140 | g̃ [τ(g̃) =10 ns] 2.2 | m(χ̃⁰₁)=100 GeV | 2205.06013
ℓ̃ℓ̃, ℓ̃→ℓG̃ | Displ. lep E_T^miss | 140 | ẽ,μ̃ 0.7 | τ(ℓ̃) = 0.1 ns | 2011.07812
τ̃ 0.34 | τ(ℓ̃) = 0.1 ns | 2011.07812
pixel dE/dx E_T^miss | 140 | τ̃ 0.36 | τ(ℓ̃) = 10 ns | 2205.06013
RPV
χ̃±₁χ̃∓₁/χ̃⁰₂, χ̃±₁→Zℓ→ℓℓℓ | 3 e,μ | 140 | χ̃±₁/χ̃⁰₂ [BR(Zτ)=1, BR(Ze)=1] 0.625 1.05 | Pure Wino | 2011.10543
χ̃±₁χ̃∓₁/χ̃⁰₂ → WW/Zℓℓℓℓνν | 4 e,μ 0 jets E_T^miss | 140 | χ̃±₁/χ̃⁰₂ [λ₁₃₃ ≠ 0, λ₁₂₄ ≠ 0] 0.95 1.55 | m(χ̃⁰₁)=200 GeV | 2103.11684
g̃g̃, g̃→qqχ̃⁰₁, χ̃⁰₁ → qqq | ≥8 jets | 140 | g̃ [m(χ̃⁰₁)=50 GeV, 1250 GeV] 1.6 2.25 | Large λ''₁₁₂ | To appear
t̃t̃, t̃→tχ̃⁰₁, χ̃⁰₁ → tbs | Multiple | 36.1 | t̃ [λ''₃₂₃=2e-4, 1e-2] 0.55 1.05 | m(χ̃⁰₁)=200 GeV, bino-like | ATLAS-CONF-2018-003
t̃t̃, t̃→bχ̃±₁, χ̃±₁ → bbs | ≥ 4b | 140 | t̃ Forbidden 0.95 | m(χ̃±₁)=500 GeV | 2010.01015
t̃₁t̃₁, t̃₁→bs | 2 jets + 2 b | 36.7 | t̃₁ [qq, bs] 0.42 0.61 | | 1710.07171
t̃₁t̃₁, t̃₁→qℓ | 2 e,μ 2 b | 36.1 | t̃₁ 0.4-1.45 | BR(t̃₁→be/bμ)>20% | 1710.05544
1 μ DV | 136 | t̃₁ [1e-10< λ'₂₃₄ <1e-8, 3e-10< λ'₂₃₄ <3e-9] 1.0 1.6 | BR(t̃₁→qμ)=100%, cosθ_t=1 | 2003.11956
χ̃±₁/χ̃⁰₂/χ̃⁰₁, χ̃⁰₁,₂→tbs, χ̃⁺₁→bbs | 1-2 e,μ ≥6 jets | 140 | χ̃⁰₁ 0.2-0.32 | Pure higgsino | 2106.09609
10⁻¹
1
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

Summary

* **A broad overview on the SUSY searches in LHC is presented with full Run2 data analyzed, including the most interesting results from EWK combination and pMSSM interpretations.**

* **No discovery yet, the limits are probed in new/challenge scenarios, with various novel techniques developed.**

* **Early Run3 analysis is starting up… looking forward.**

* **For your interest, please visit: ATLAS Publication Web and CMS Publication Web.**

Extra slides