Recent searches for SUSY in CMS

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LHCP 2023
21-26 May 2023, Belgrade

SUSY searches at CMS

CMS continues a rich and lively SUSY search program:

- 28 public results with multi-year CMS Run 2 data covering a wide range of SUSY signatures.
- Wide spectrum of searches: Inclusive, multi-bin searches looking at multiple final states; dedicated searches targeting a specific final state.
- Recent focus on more challenging final states: compressed spectra, low cross sections (e.g. sleptons), long-lived particles, low p_T^{miss} (e.g. RPV, stealth), … .
- Developing methodologies to handle difficult final states:
  - Analysis combination, increased use of machine learning, refined object identification, …

In this talk: 4 most recently public CMS SUSY results.

- EWKino combination
- Photon + jets + E_T^{miss}
- Stealth SUSY with 2 photons + jets + low E_T^{miss}
- Inclusive disappearing track — first time in this conference!

EWKino searches combination

CMS-PAS-SUS-21-008

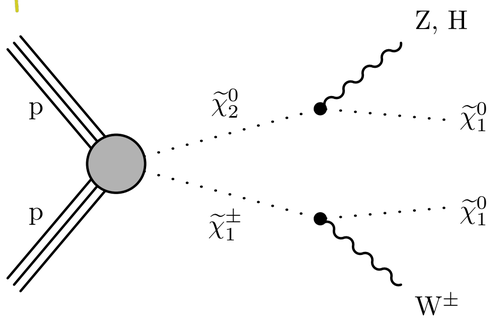
- Direct EWKino production or slepton production have (very) low cross sections.
- Combination of searches is crucial for enhanced sensitivity and reach complementarity.
- New combination of 6 EWKino searches with full Run 2 data (update on 2016 study):

	ideal for compressed scenarios	ideal for semi-compressed scenarios	
leptonic	**"2/3 lep soft"** *2 or 3 e/μ* *Opposite-sign same flavor pair* *5(3.5) < p_T^{lep} < 30* CMS-SUS-18-004	**"≥3 lep"** *>3l + p_T^{miss} (parametric NN)* *or same sign dilepton + p_T^{miss}* *Leading lep p_T > 30* CMS-SUS-19-012	**"Zll on-Z / non-resonant"** *e^+e^- or $\mu^+\mu^-$* *On-shell or off-shell Z* CMS-SUS-20-001
semileptonic or hadronic	**"1l 2b WH"** *1 e/μ + H(bb) + MET* *Resolved and boosted H(bb)* CMS-SUS-20-003	**"4b HH"** *No leptons* *H(bb) H(bb) + MET* *Resolved and boosted H(bb)* CMS-SUS-20-004	**"Hadr. WX"** *Fully hadronic final state* *≥2 AK8 jets, 2-6 AK4 jets* *Boosted W,Z,H* CMS-SUS-21-002
		ideal for semi (large) mass splittings	ideal for large mass splittings

- Interpreted with 4 different signal model schemes (2 shown here).

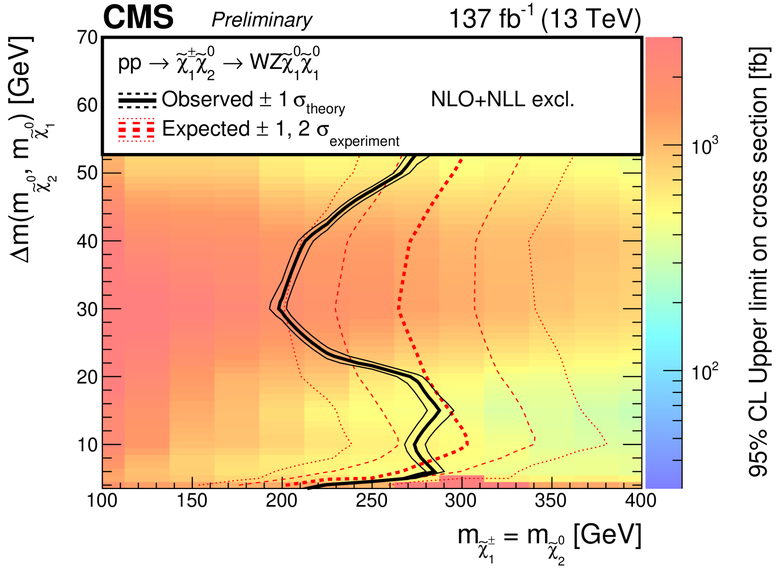
EWK comb: C1/N2 production to WZ/WH

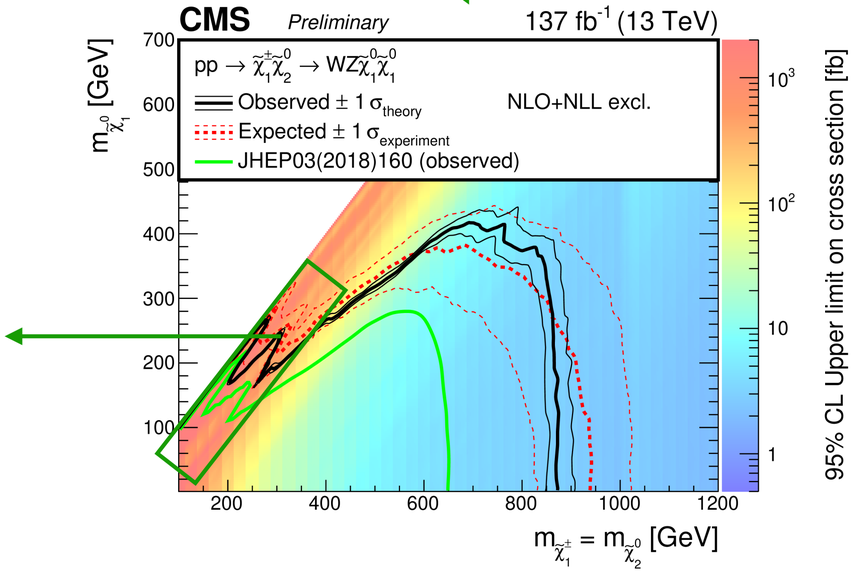
CMS-PAS-SUS-21-008

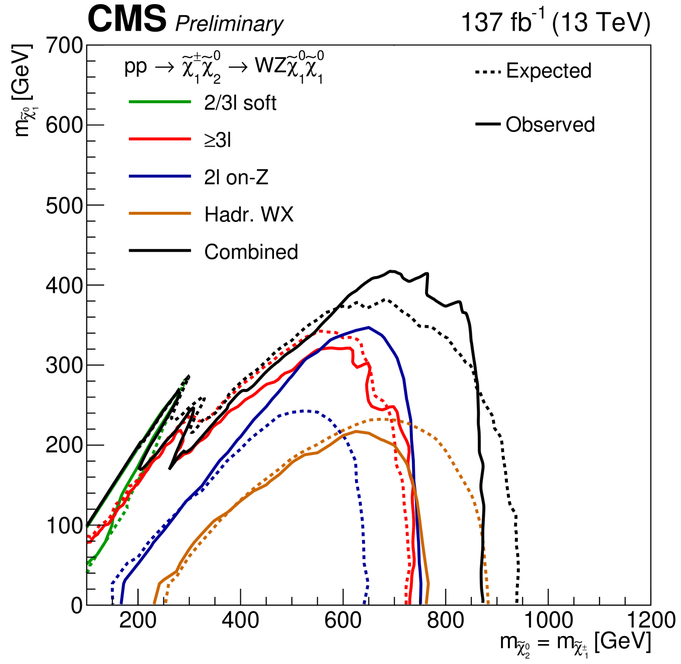


- Compressed region: Soft lepton analysis dominates. New parametric signal extraction optimizes binning.
- Uncompressed region: Boosted W/Z/H-tagged hadronic final states add new sensitivity.

Search	Gaugino	
	WZ	WH
$2/3\ell$	✓	
2ℓ on-Z	✓	
2ℓ non-res		
$\geq 3\ell$	✓	✓
$1\ell 2b$		✓
$4b$		
Hadr. WX	✓	✓

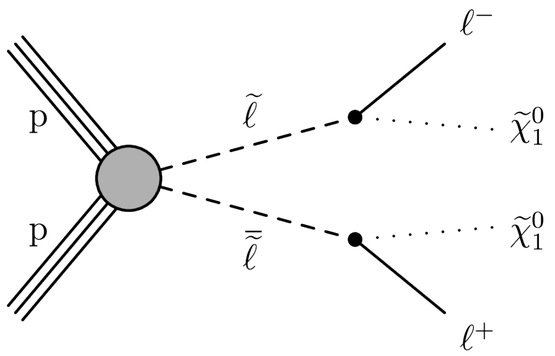






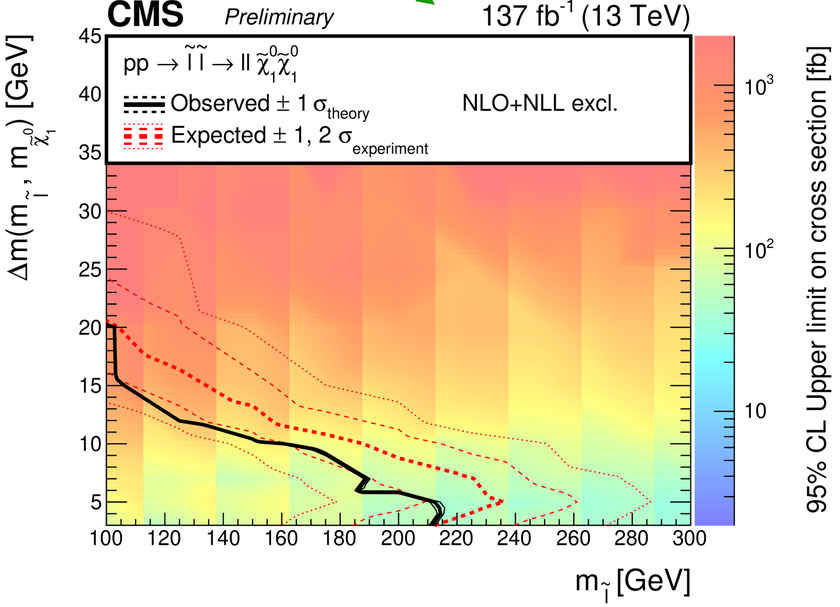
EWK comb: Sleptons

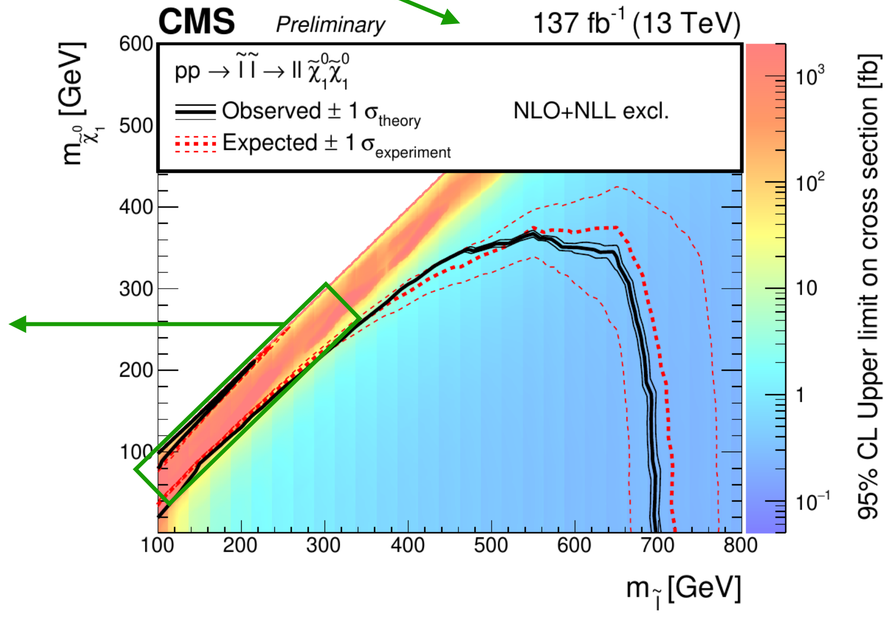
CMS-PAS-SUS-21-008



- Particularly difficult due to very small cross sections.
  - Degenerate 1st/2nd gen leptons (left and right-handed).
- 2/3l soft targets compressed, 2l non-resonant non-compressed cases.

Search	Slepton
	$\ell^+\ell^-$
$2/3\ell$	✓
2ℓ on-Z	
2ℓ non-res	✓
$\geq 3\ell$	
$1\ell 2b$	
$4b$	
Hadr. WX	





Other models (not shown): EWKinos in GMSB, Higgsino-bino.

Stealth SUSY with diphotons + low p_T^{miss}

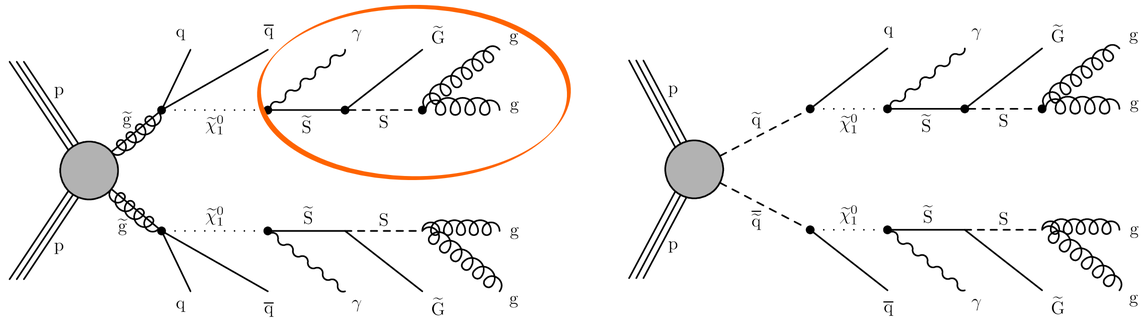
CMS-PAS-SUS-19-001

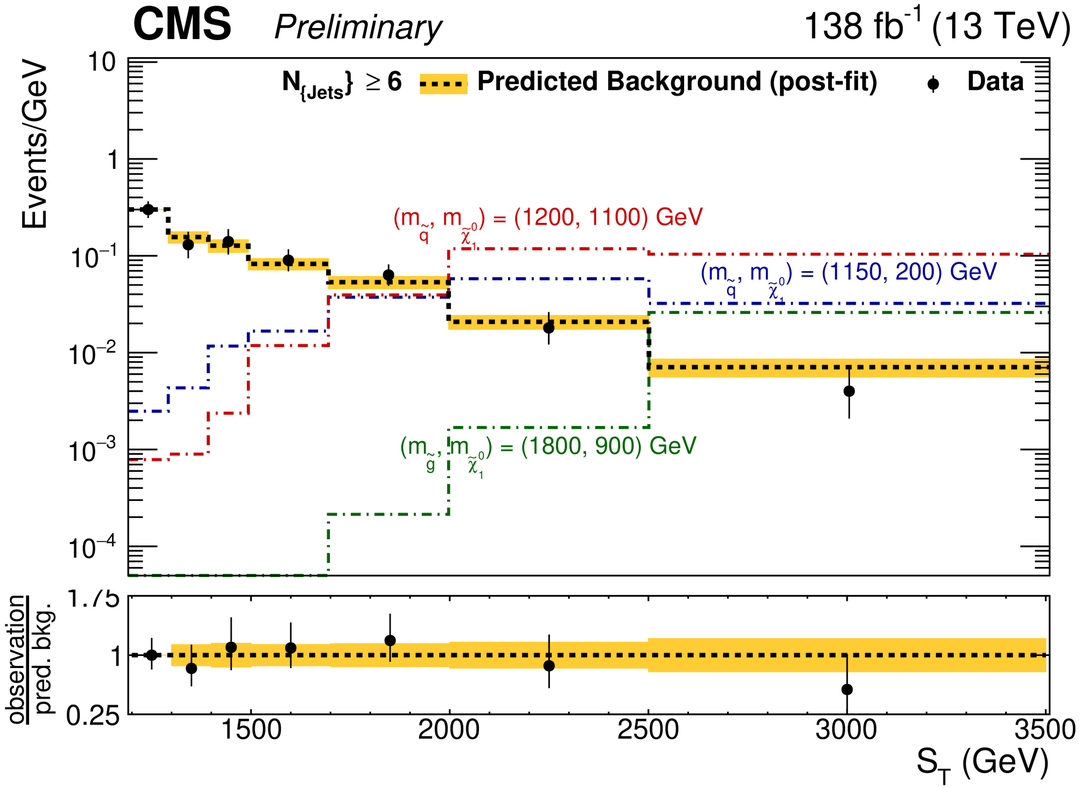
Stealth SUSY: MSSM + weak scale light hidden sector, weakly coupling to SUSY.

- Mass-degenerate singlet S and singlino ~S.
- Gravitino LSP produced in ~S decays.
- Low $\Delta m(\tilde{S}, S) \Longrightarrow$ low p_T ~G $\Longrightarrow$ low p_T^{miss}.

Search for strongly produced stealth SUSY:

- 2 photons (p_T > 35/25) + ≥4 jets + low p_T^{miss},
- S_T > 1200 GeV (scalar sum of all object p_Ts).
- Data-driven BG estimation using S_T shape derived at low jet multiplicity.
- Extract signal in S_T distribution in bins of jet multiplicity (4, 5, ≥6 jets).



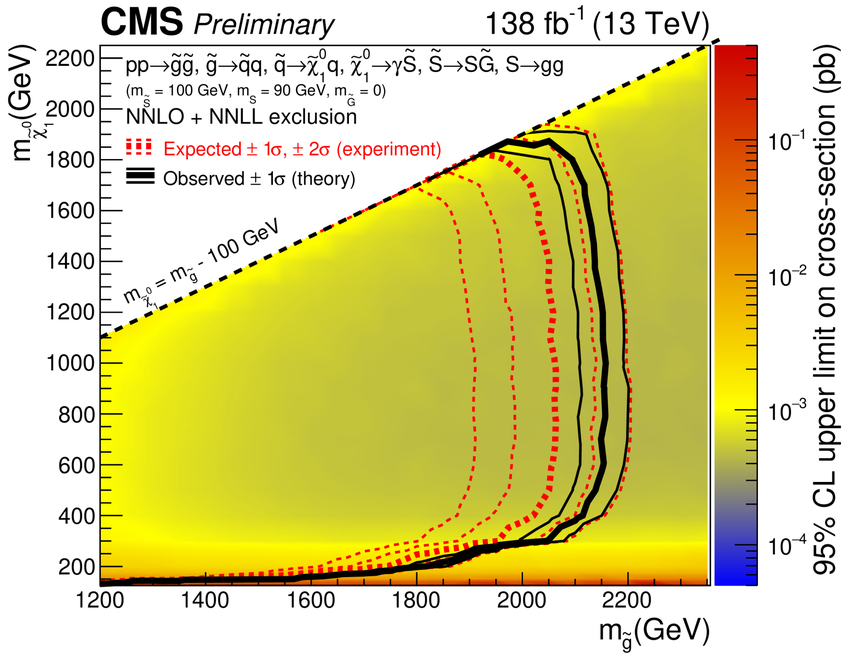


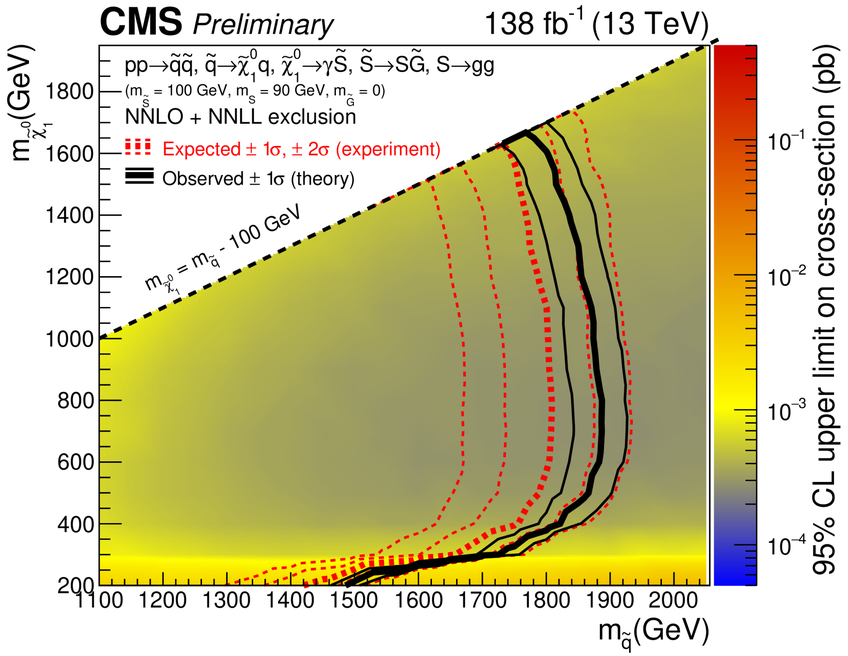
Stealth SUSY with 2γ + jets + low p_T^{miss}

CMS-PAS-SUS-19-001

Gluino and light squark limits for fixed singlino, singlet and gravitino masses:

Most stringent limits obtained on these models.





Exclude gluinos up to 2.15 TeV.

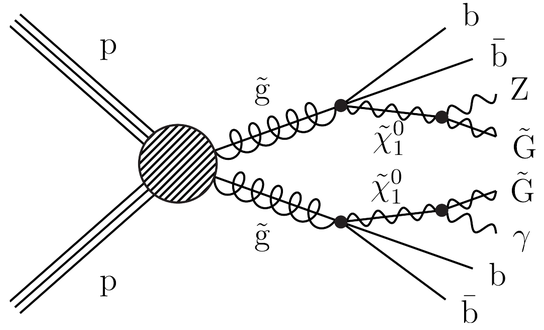
Exclude squarks up to 1.85 TeV.

γ + multijets + p_T^{miss} search

CMS-PAS-SUS-21-009

GMSB: LSP is a light gravitino ~G.

For massive sleptons, N1 → Z/h/~G, C1 → W~G prominent decays.

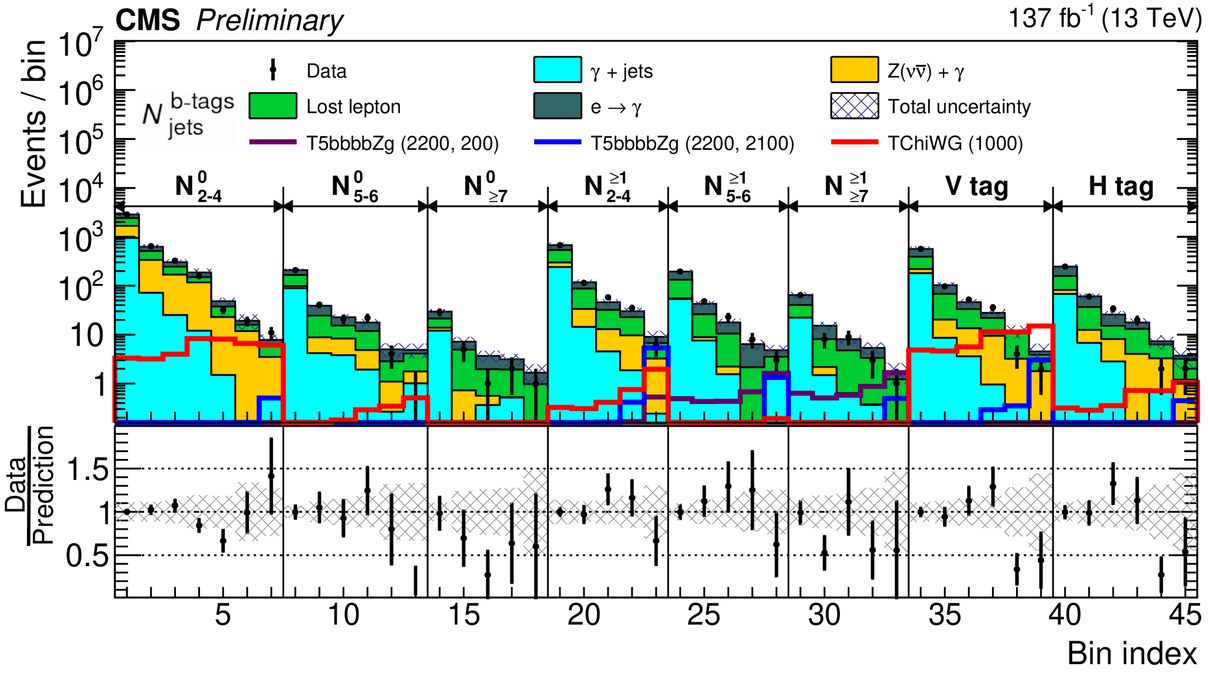


SUSY search with ≥1 high p_T γ + multijets + p_T^{miss} final state.

- Optimized analysis for strong production.
- Dedicated search regions for direct EWKino pair production with boosted W/Z/H via AK8jet mass.

$N_\gamma\ (p_T > 100)$	≥ 1	$S_T = \sum_{jets} p_T^{jet} + p_T^{\gamma,1}$	> 300 GeV
N_{jets}	≥ 2	$N_e,\ N_\mu,\ N_{isotrack}$	$= 0$
p_T^{miss}	> 300 GeV	$\Delta\phi(p_T^{jet,1,2}, p_T^{miss})$	> 0.3

- Orthogonal bins of N_j, N_b, N_V, N_H, p_T^{miss}. ➡
- Backgrounds estimated by transfer factors applied to data control regions.
- Data consistent with the SM.

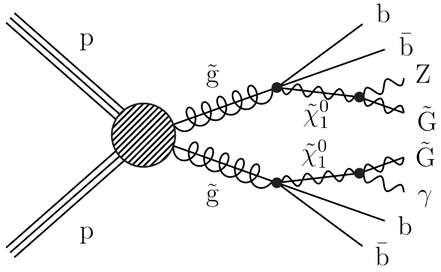


Bins of increasing p_T^{miss}. 1st bins [200, 300] show control regions, rest show signal regions.

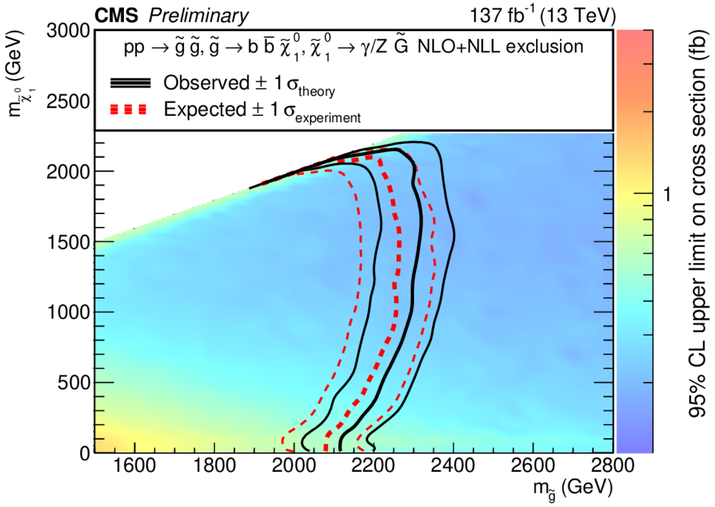
γ + multijets + p_T^{miss} search

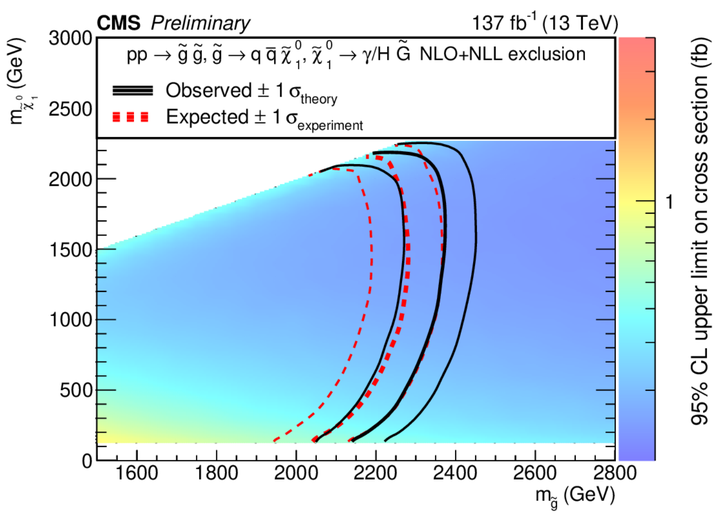
CMS-PAS-SUS-21-009

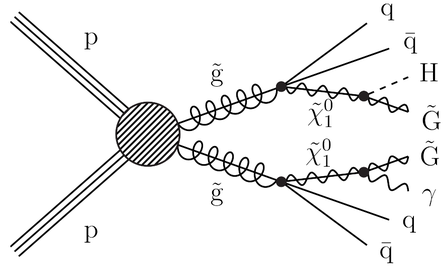
Gluino and top squark mass limits:



~g up to 2.32 TeV.

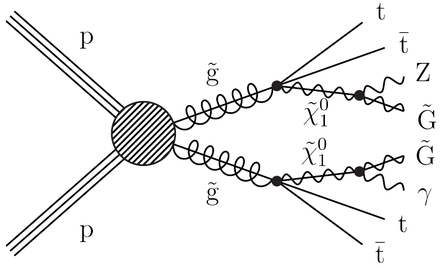


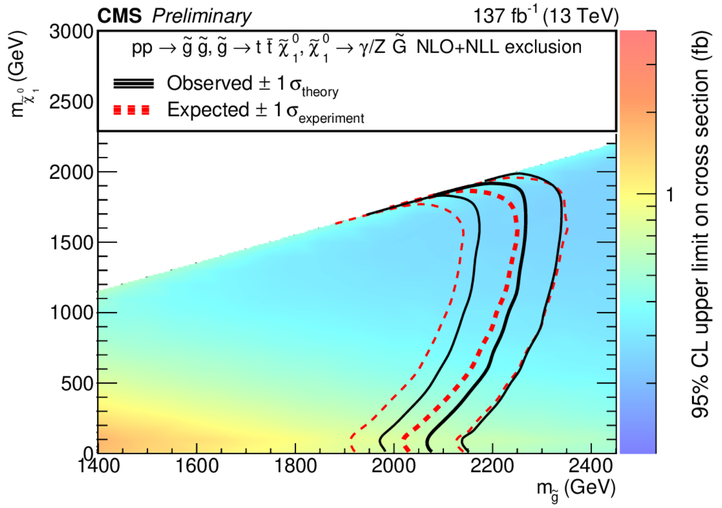


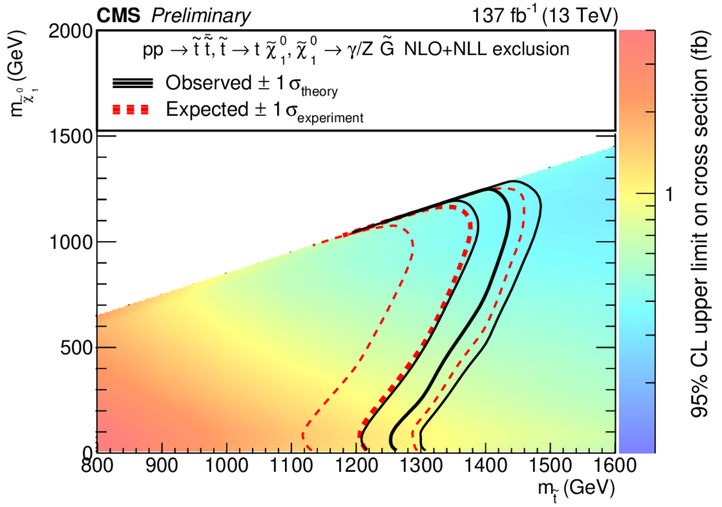


~g up to 2.35 TeV (similar to ATLAS).

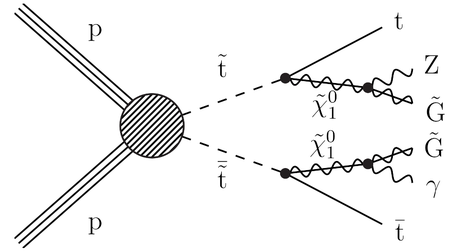
~g up to 2.26 TeV.







~t up to 1.43 TeV (similar to ATLAS).



γ + multijets + p_T^{miss} search

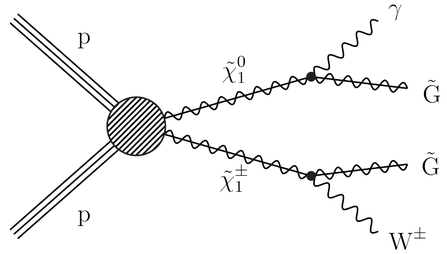
CMS-PAS-SUS-21-009

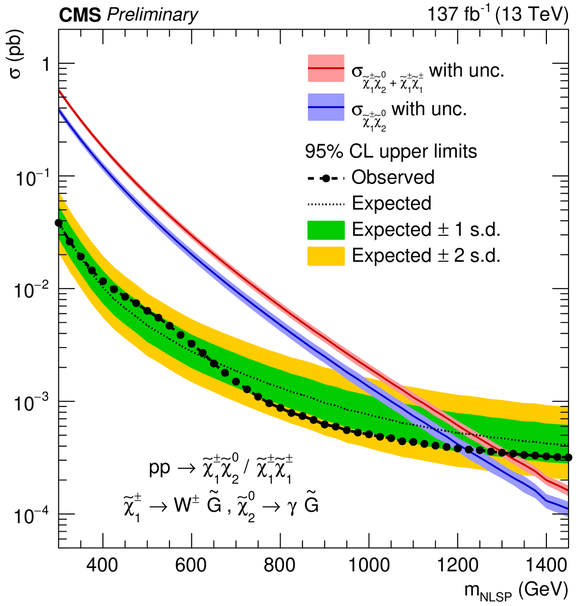
EWK limits:

- Assume wino or higgsino cross sections.
- Assume one or more production mechanisms.

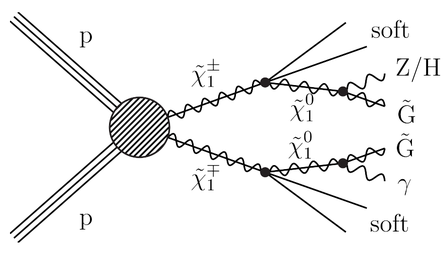
Chargino / neutralino exclusion:

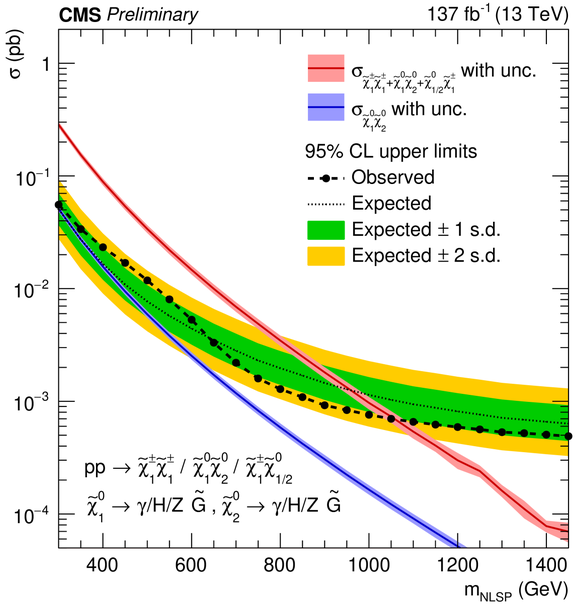
Wino-like: ~1.3 TeV
Higgsino-like: ~1.05 TeV



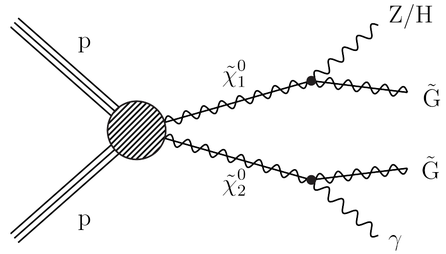


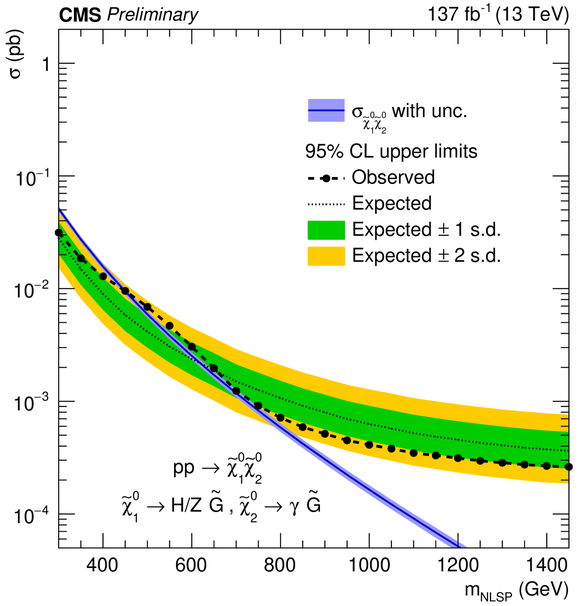
Wino-like





Higgsino-like





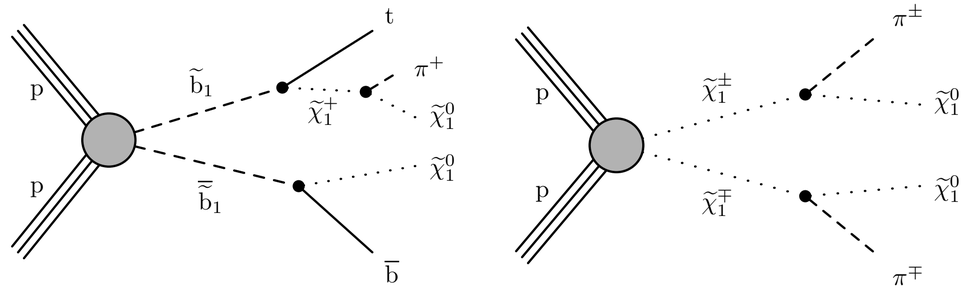
Higgsino-like.

Disappearing track

NEW!

CMS-PAS-SUS-21-006

Compressed SUSY with Δm(C1, N1) ~ O(100 MeV),
⟹ C1 is long lived.
⟹ decays inside tracker to a soft undetectable $\pi^{\pm}$ + p_T^{miss}
⟹ disappearing track (DTk) signature.

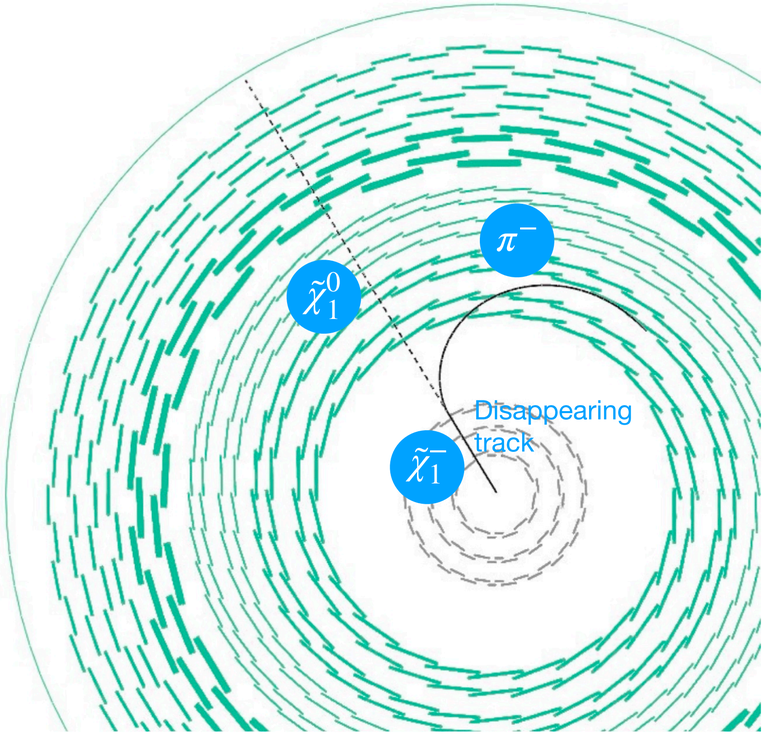


1 / ≥2 disappearing track + p_T^{miss} + ≥1 jet + 0/1 lepton:

- Target long-lived C1 from strong or EWK production.

- DTk selection: Categorize into short (pixel-only) and long (pixel+strip) DTk selections to search for a range of lifetimes.
  - Negligible energy deposits in the calorimeters.
  - Boosted decision tree classifiers used to improve DTk purity.

First time at LHC for DTks!

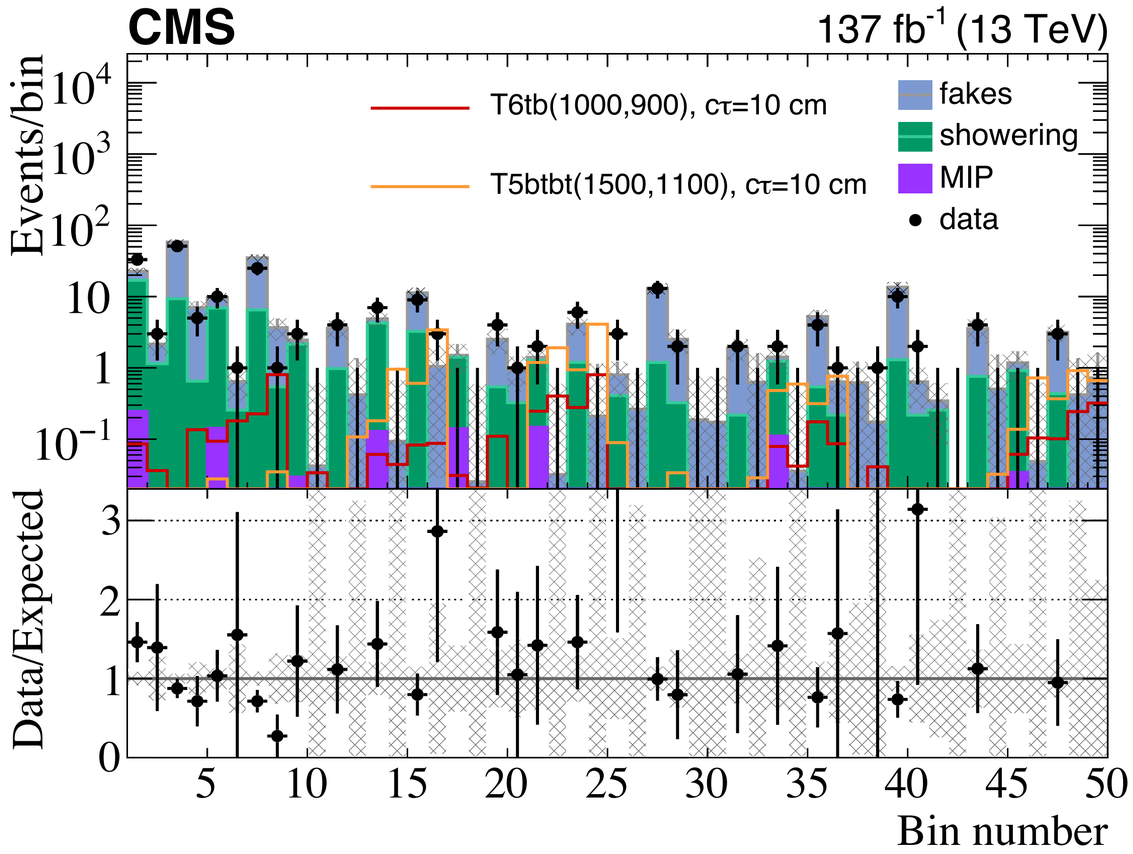


Disappearing track: BG estimate, results

NEW!

CMS-PAS-SUS-21-006

- 3 channels: hadronic+DTk, e+DTk, μ+DTk.
- 49 search bins in hard p_T^{miss}, $N_{b\text{-jets}}$, N_{jets}, $N_{short\text{-}tracks}$, $N_{long\text{-}tracks}$, pixel dE/dx.
- Backgrounds: 1) Hadrons and leptons poorly reconstructed in tracker; 2) tracks built out of chance alignment of hits from different particles.
- Background estimation: Data-driven. Calculate transfer factors in sideband regions and apply to DTk candidates in control regions.



First time at LHC for DTks!

Data consistent with the SM.

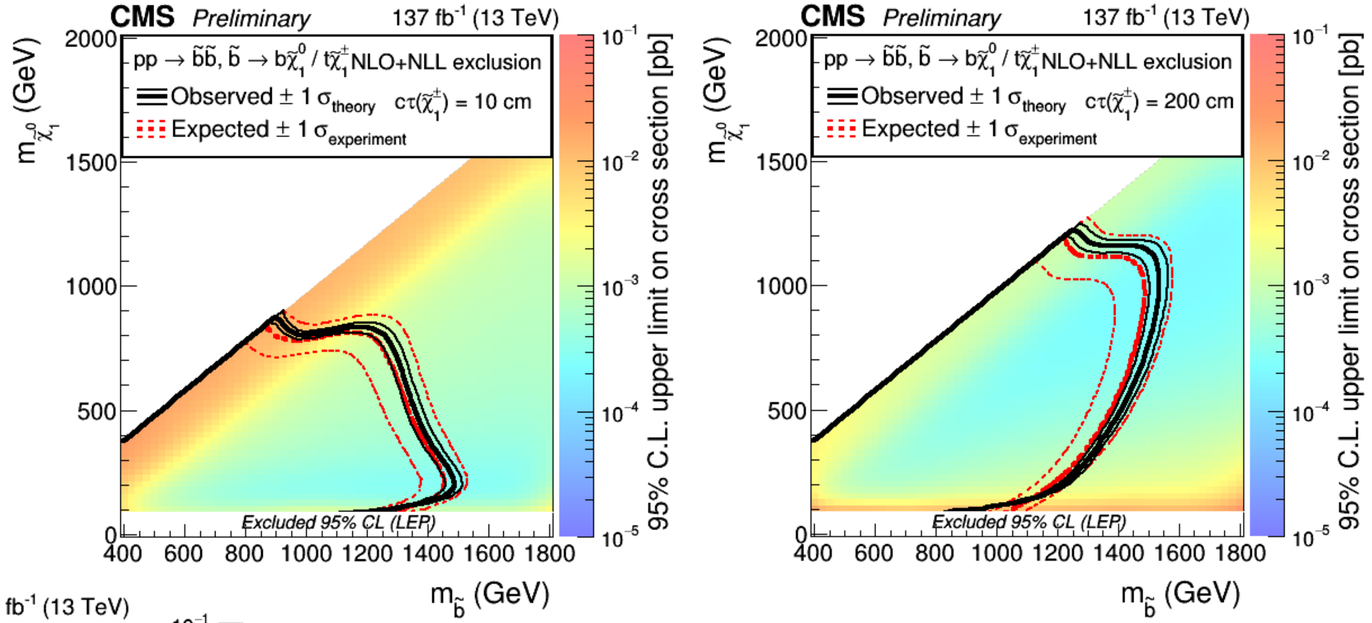
Disappearing track: Interpretation

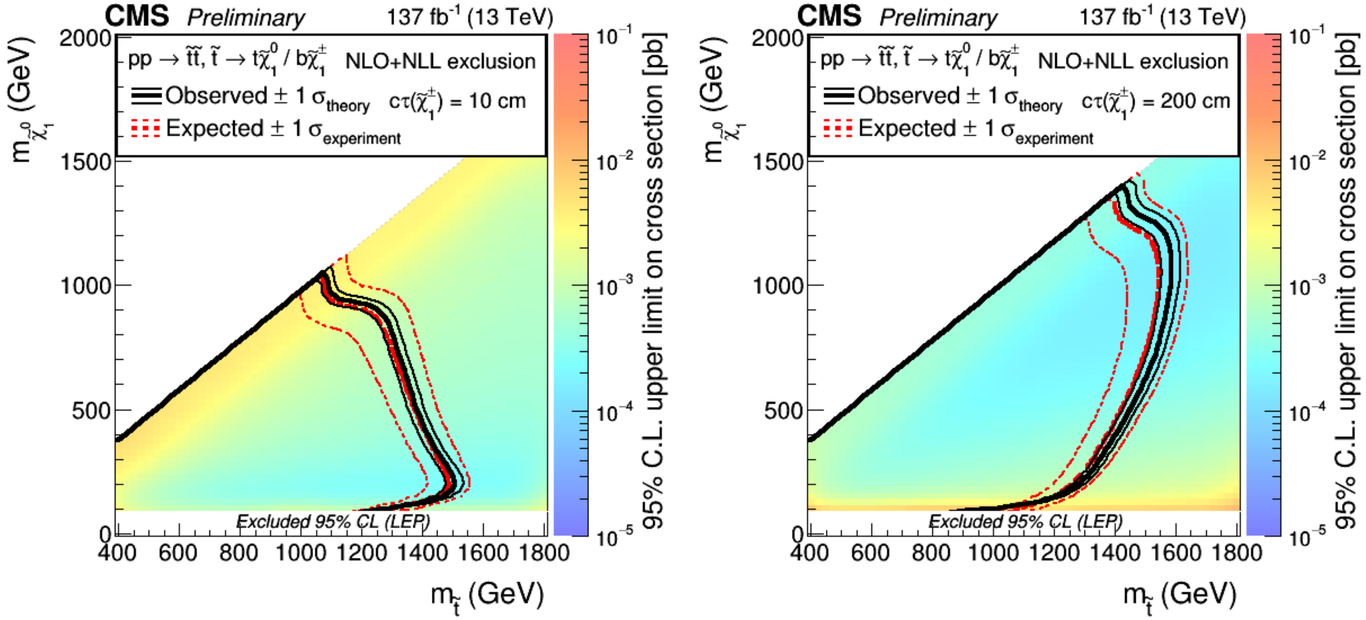
NEW!

CMS-PAS-SUS-21-006

~b, C1/N1 mass reach up to ~1.5 TeV, ~1.1 TeV for cτ = 200 cm.

Up to ~500 GeV C1/N1 mass improvement in the compressed region wrt. prompt searches (esp. for long lifetimes).





~t, C1/N1 mass reach up to ~1.6 TeV, ~1.4 TeV for cτ = 200 cm.

~>200 GeV C1/N1 improved reach in compressed region wrt. previous DTk search (SUS-19-005).

Contr. from leptonic channels.

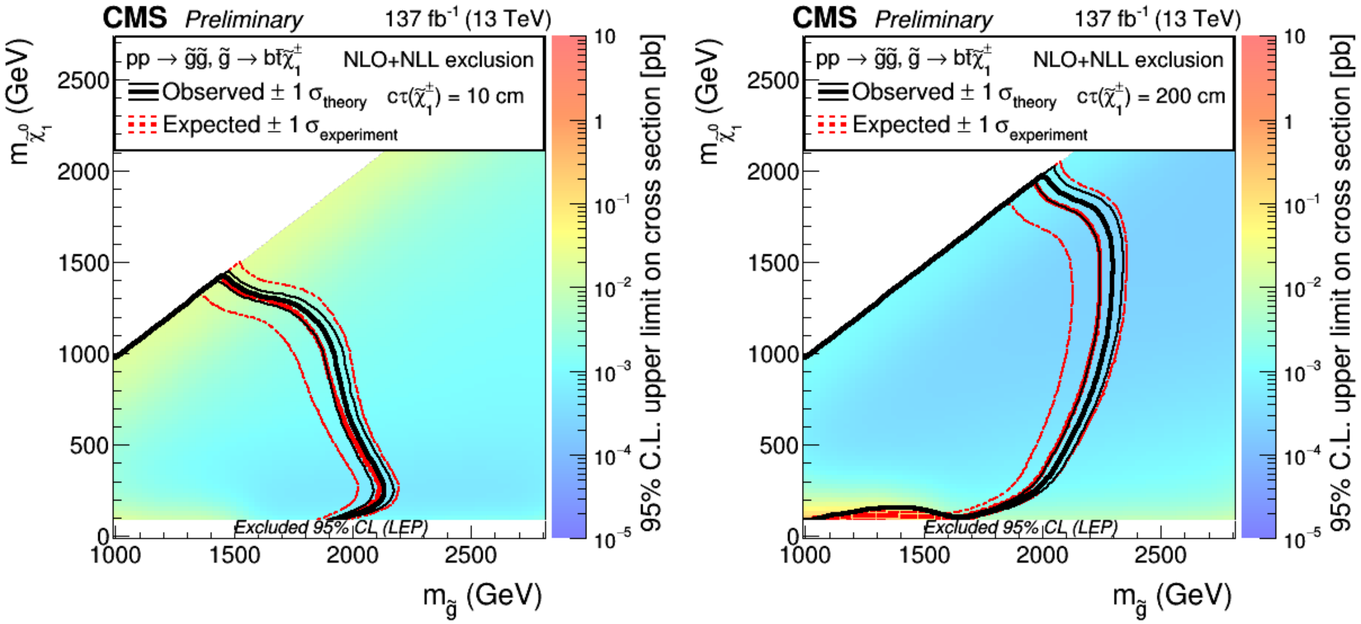
Disappearing track: Interpretation

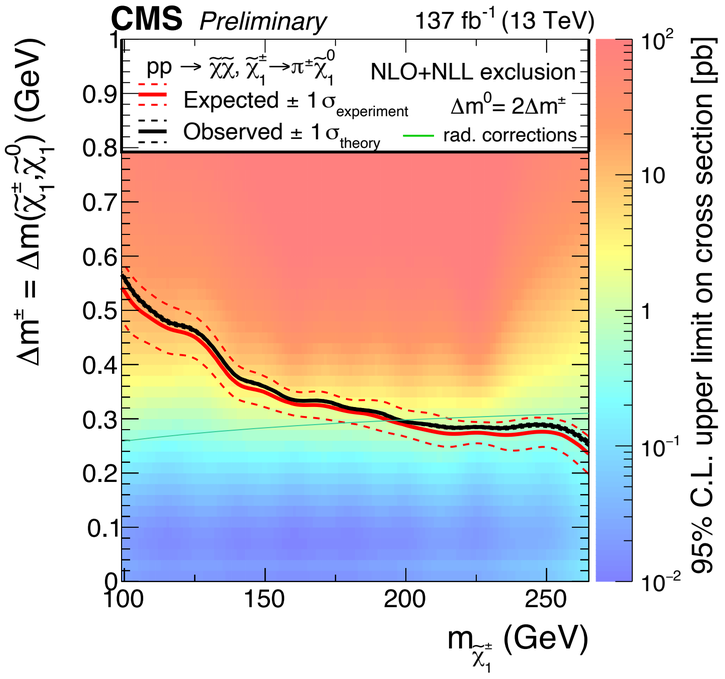
NEW!

CMS-PAS-SUS-21-006

~g, C1/N1 mass reach up to ~2.3 TeV , ~2 TeV for cτ = 200 cm.

Up to ~500 GeV C1/N1 mass improvement in the compressed region wrt. prompt searches (esp. for long lifetimes)., e.g. wrt. ~g —> bbN1, ttN1





Higgsino model: Fully degenerate N1, N2, C1 with a dominant Higgsino component.

arXiv:1703.09675

- Direct EWKino production.
- Cross section affected by the Higgsino nature. Sum of all processes.
- Exclude C1 up to ~200 GeV.

$\tilde{\chi}_2^0\tilde{\chi}_1^\pm \quad \tilde{\chi}_2^0 \to Z^*\tilde{\chi}_1^0,\ \tilde{\chi}_1^\pm \to \pi^\pm\tilde{\chi}_1^0$

$\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm \quad \tilde{\chi}_1^\pm \to \pi^\pm\tilde{\chi}_1^0,\ \tilde{\chi}_1^\pm \to \pi^\pm\tilde{\chi}_1^0$

$\tilde{\chi}_1^\pm\tilde{\chi}_1^0 \quad \tilde{\chi}_1^\pm \to \pi^\pm\tilde{\chi}_1^0,\ \tilde{\chi}_1^0$

Summary and outlook

- CMS continues to explore every corner of the SUSY parameter space.
- Presented 4 most recent results:
  - EWKino combination of 6 searches: Interpreted in 4 models. Clearly showed sensitivity complementarity of different searches. Motivate further combination studies.
  - Stealth SUSY with diphotons + low E_T^{miss}: Low-ETmiss search sensitive to stealthy hidden sectors.
  - ≥1 γ + multijets + E_T^{miss}: Reoptimized hadronic channels, dedicated EWK channels.
  - Disappearing track inclusive: First LHC search with lepton+disappearing track. Hundreds of GeV sensitivity improvement in the compressed region.
- Exploration continues — more searches are on the way!