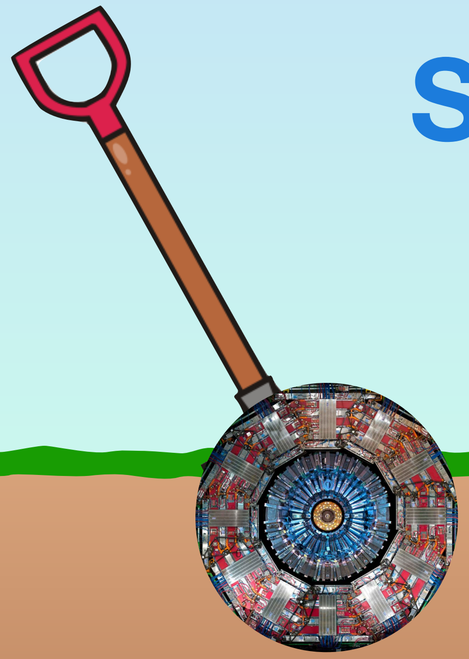

Digging deeper into SUSY parameter space with the CMS Experiment

Sezen Sekmen
Kyungpook National University
for the CMS Collaboration

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Diversifying the search for SUSY

Classical SUSY searches have not yet provided an evidence for SUSY, e.g.

inclusive searches; stop searches (S. Bhattacharya); leptonic searches (A. Mohamed)

Yet SUSY can be hidden in distant, unique corners of the parameter space.

We are designing an increasing diversity of dedicated searches to explore such corners:

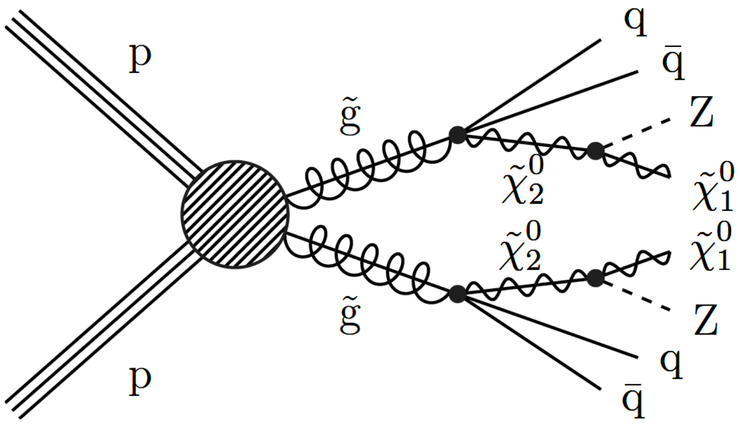
- Compressed mass spectra ⟹ searches with soft objects + ISR jets, searches using long-lived particle signatures.
- Higher masses and mass differences ⟹ searches with boosted objects.
- Models with accessible sleptons / staus ⟹ exclusive searches for sleptons / staus.
- Cascades with Higgs ⟹ searches with reconstructed Higgs bosons.
- Signatures with specific combinations of objects ⟹ searches with γ+b, γ+lepton, …
- RPV models: searches with no missing transverse energy, high multiplicity

Will present 3 recent non-classic search examples from CMS in this talk.

Boosted ZZ + p_T^{miss}

CMS SUS-19-013 (137 fb^{-1})

Gluino decays cascading via massive N2 to light N1. Motivated by Natural SUSY.



Large $\Delta m(N2 - N1) \Longrightarrow$ 2 highly boosted Zs and p_T^{miss}.

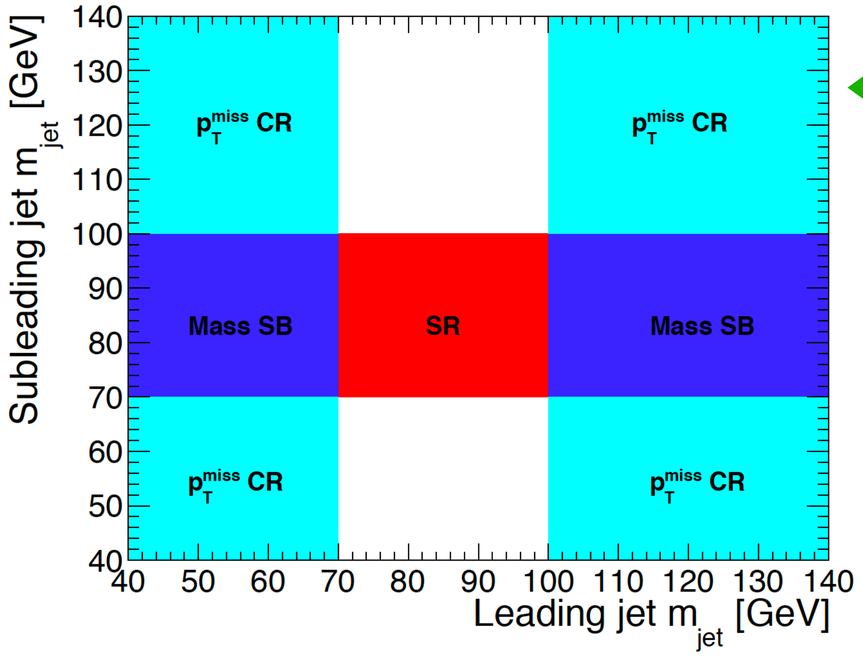
- Selection: 0 leptons, ≥2 Zs, ≥ 2 jets, $p_T^{miss} > 300$, $H_T > 400$.
- Z candidates: AK8 jets with $p_T > 200$, $40 < m_{AK8} < 140$. $\Delta R(Z_2, b) > 0.8$ (2nd highest p_T Z and any b jet).

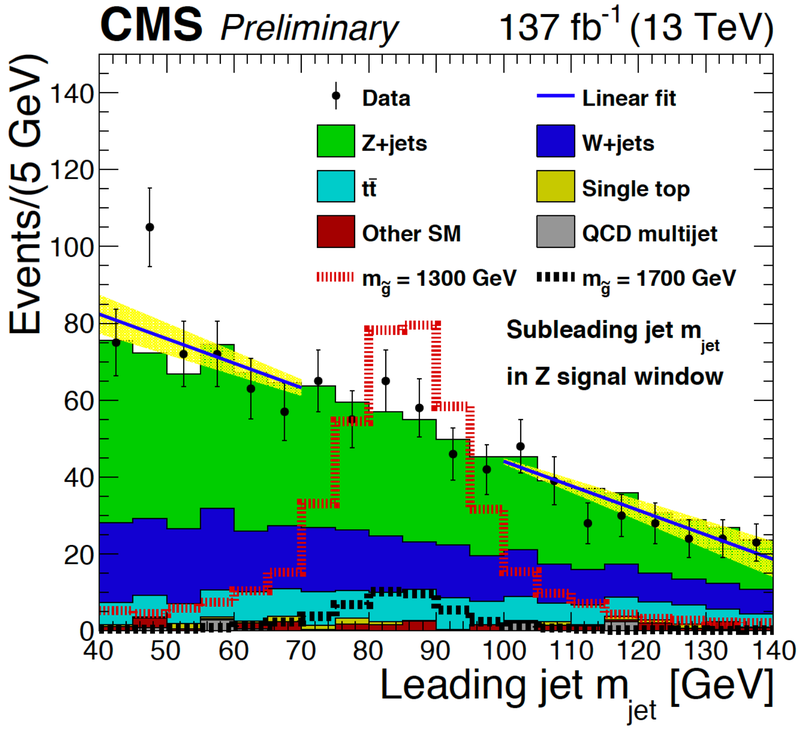
Main BG: Z(→νν)+jets.

Control regions defined using masses of Z candidates:

Mass sideband: Fit leading AK8 jet mass distribution to estimate BG normalization integrated over p_T^{miss}.

p_T^{miss} control region: derive p_T^{miss} shape (m_{jet} and p_T^{miss} have minimal correlation)



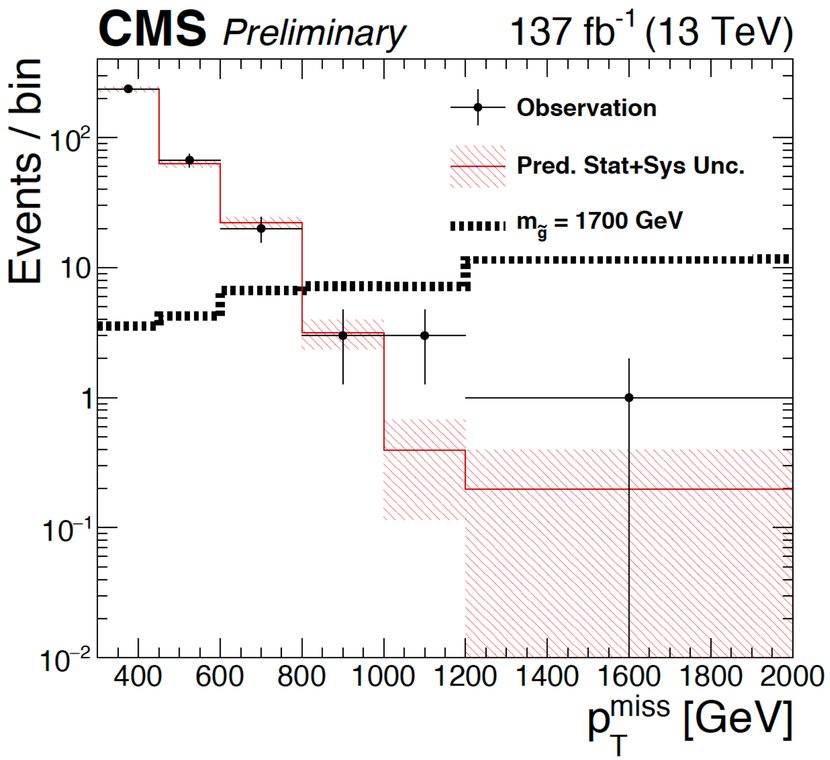


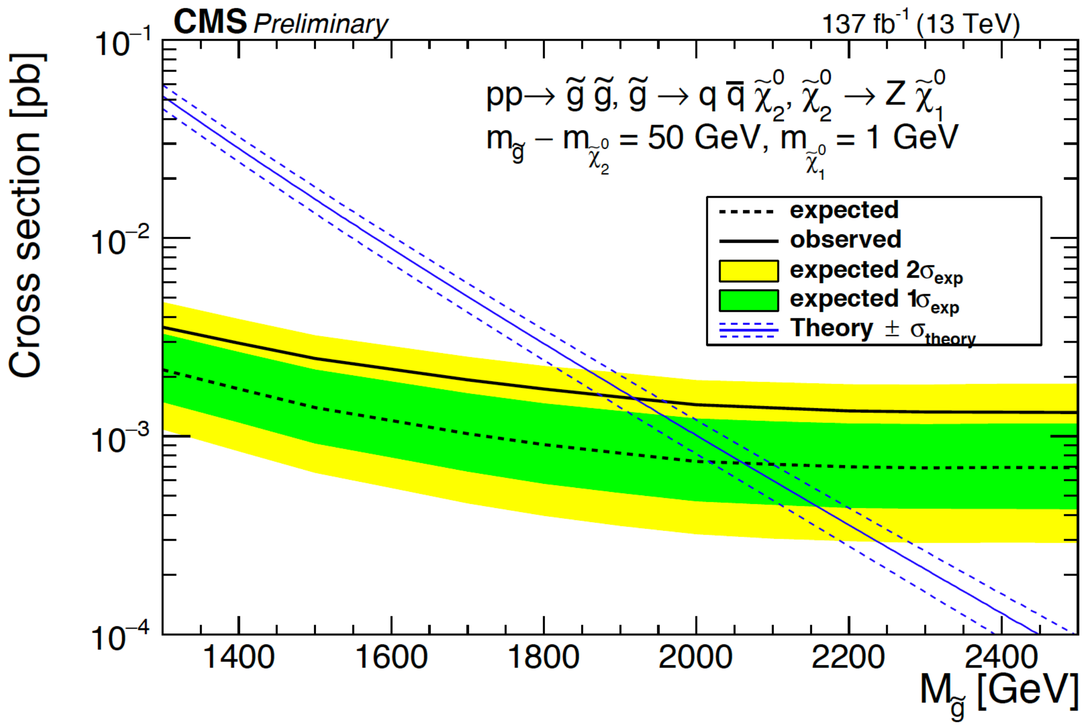
Boosted ZZ + p_T^{miss}

CMS SUS-19-013 (137 fb^{-1})

Search for an excess in p_T^{miss} bins. No excess.

Interpretation using a model with Δm(gluino - N2) = 50 GeV and m_{N1} = 1 GeV. $\Longrightarrow$ gluino decays to a low momentum quark pair and N2, N2 decays to boosted Zs + N1.

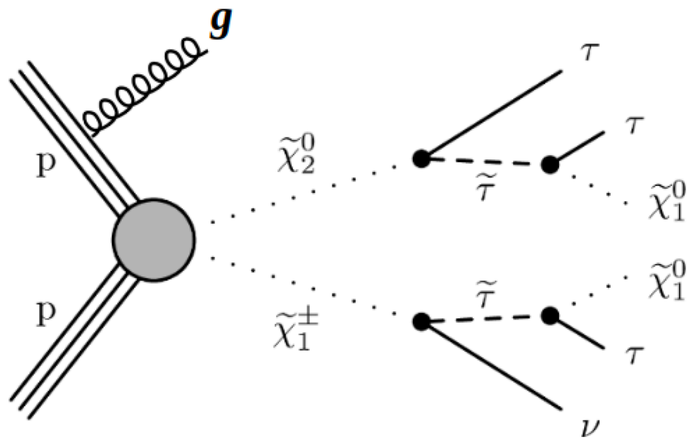




Exclude m_{gluino} < 1.9 TeV.

Compressed SUSY with soft taus

CMS SUS-19-002 (77.2 fb^{-1})



Search for staus with low Δm(stau, N1) < 50 GeV.
Compressed case favored by DM coannihilation scenarios.

Direct production of EWK gauginos or staus.

Final state with a soft hadronic τ + ISR jet + p_T^{miss}.
(first search with this signature)

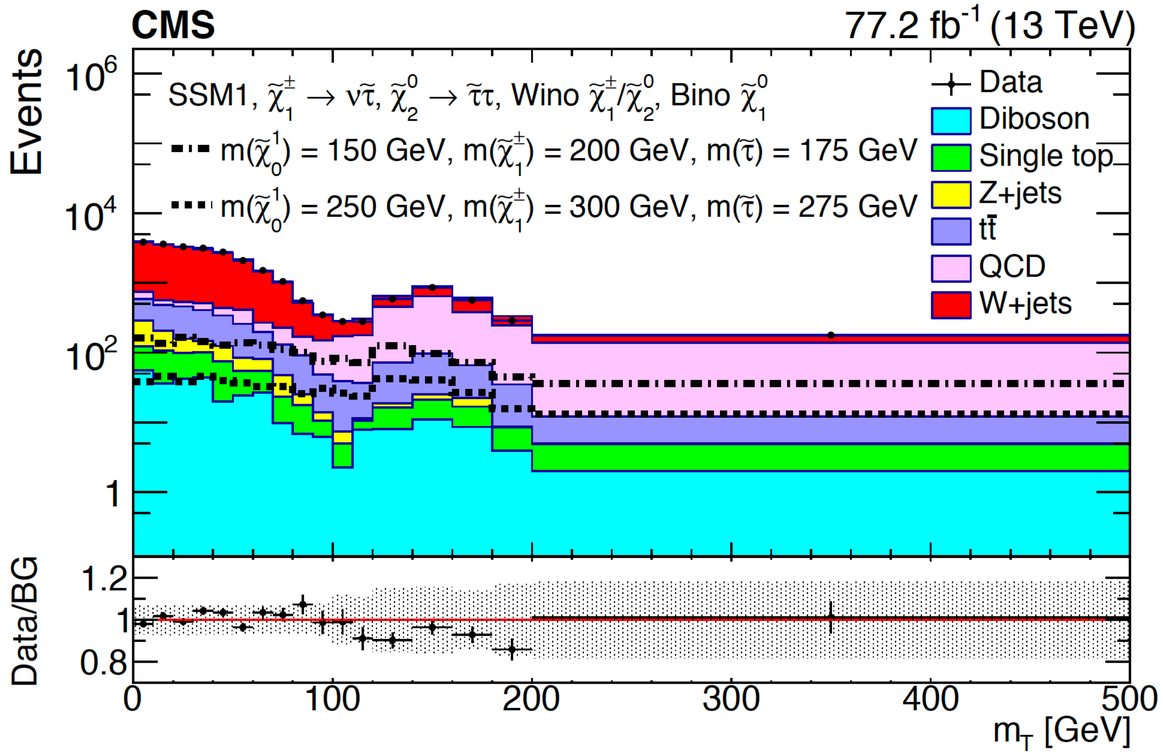
Selection: 20 < τ p_T < 40, jet p_T > 100, p_T^{miss} > 230, Δφ(ISR jet, p_T^{miss}) > 0.7, 0 b-jets,

Look for excess in: τ transverse mass m_T:

$$m_T(\vec{p}_T^{miss}, \tau_h) = \sqrt{2 p_T^{miss} p_T(\tau_h)(1 - \cos\Delta\phi(\vec{p}_T^{miss}, \tau_h))},$$

BG estimation:

- tt+jets, W/Z+jets: m_T shape from control regions, yields extrapolated using MC.
- QCD: m_T shape and yields from control regions.



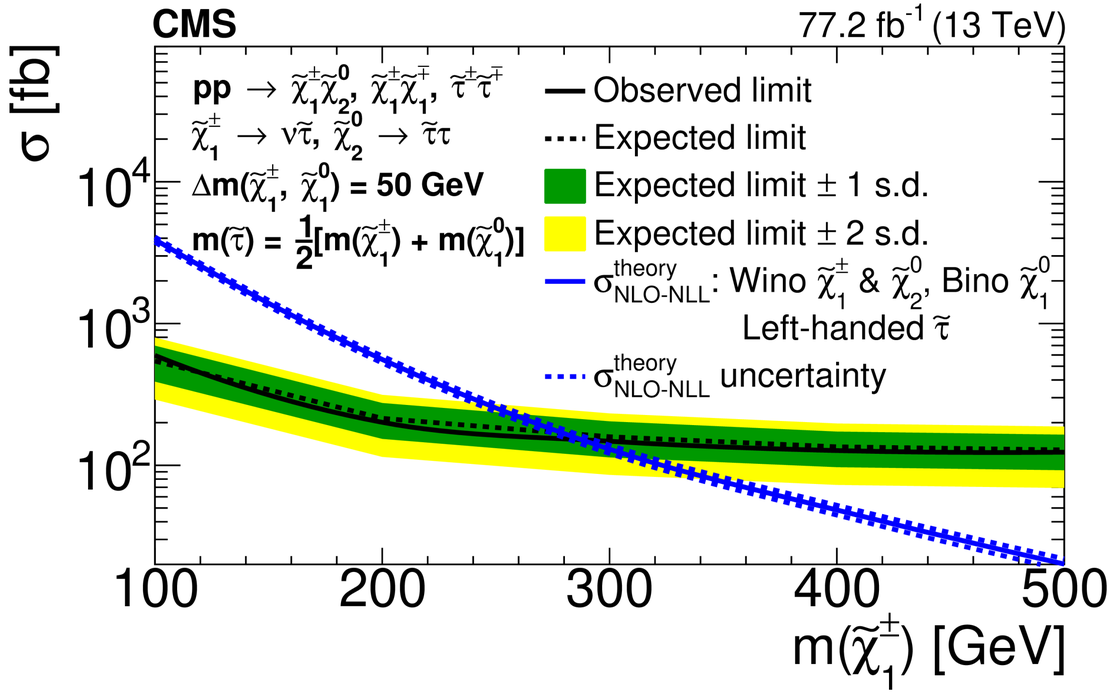
Compressed SUSY with soft taus

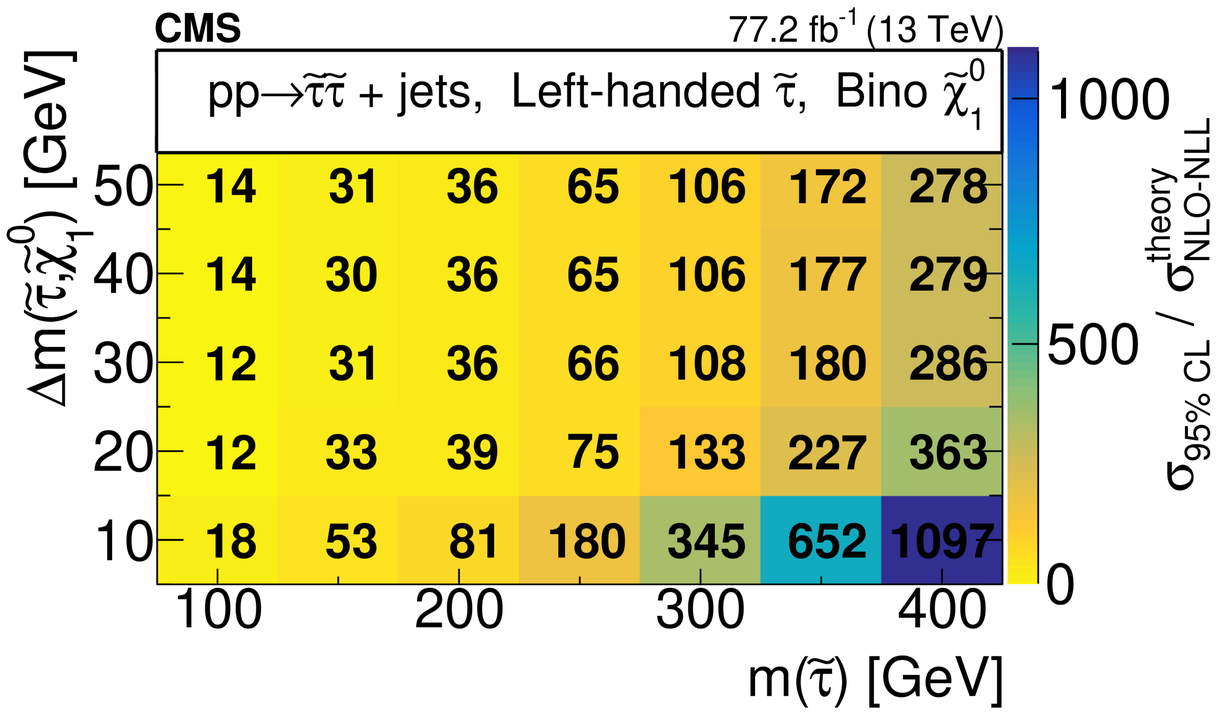
CMS SUS-19-002 (77.2 fb^{-1})

N2C1 / C1+C1- production:

For 100% wino N2/C1, Δm(stau, N1) < 50 GeV
Exclude $m_{N2/C1}$ < 290 GeV.

Most stringent limit. First study to surpass the LEP exclusion of m_{C1} < 103.5 GeV in compressed scenarios.





Stau pair production: No sensitivity yet.

Observed limit / theory limit ≥12 for m_{stau} < 100 and 20 < m_{N1} < 40.

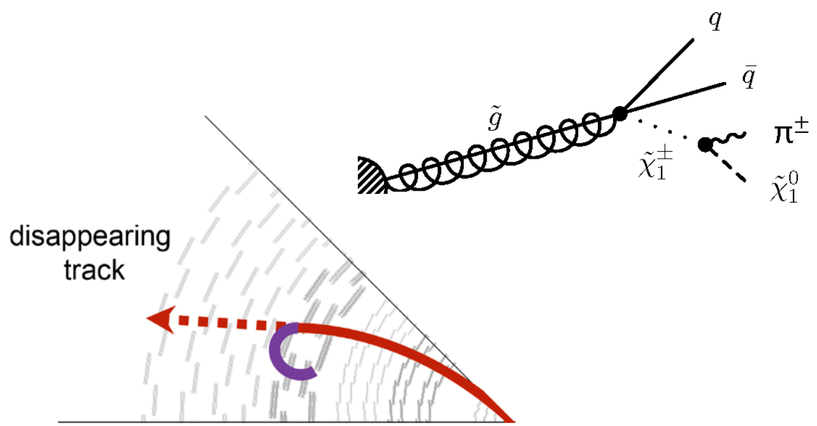
Disappearing tracks with M_{T2}

CMS SUS-19-005 (137 fb^{-1})

For compressed SUSY with $\Delta m(C1, N1) \sim O(100\ \text{MeV})$, C1 is long lived.

C1 decays inside the tracker to a soft undetectable pion + E_T^{miss} $\Longrightarrow$ disappearing track (DT) signature.

Search for compressed C1 in gluino/squark decays by extending the inclusive hadronic M_{T2} search with final states with DTs + ≥ 2 jets + M_{T2} > 200 GeV.



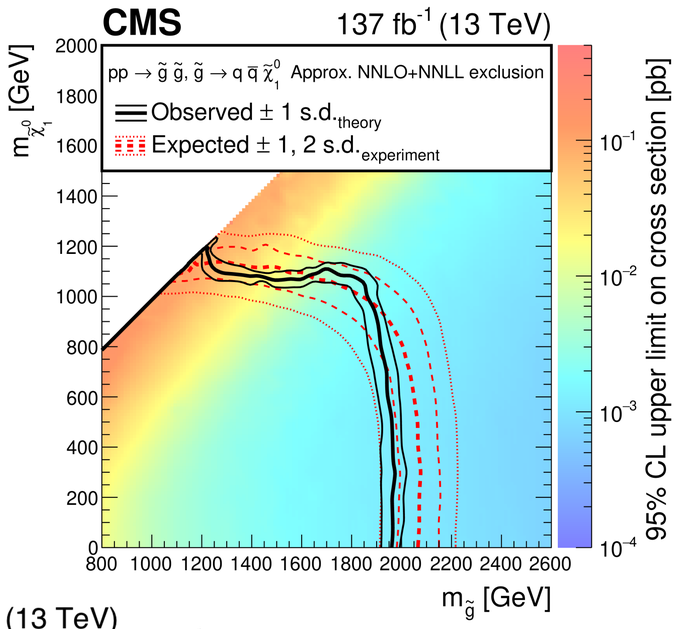
- DT selection: Categorize into short (pixel-only) and medium/long (pixel+strip) DT selections to search for a range of lifetimes.
- DT requirement allows to select looser kinematic requirements: e.g. M_{T2} > 400 GeV → M_{T2} > 200 GeV.
- Search bins in N_{jets}, H_T, DT length, DT p_T (68 search regions).
- Backgrounds: 1) Hadrons and leptons poorly reconstructed in tracker; 2) tracks built out of incorrect combination of hits.
- Background estimation: Calculate fake rate in data control regions and apply to DT candidates.

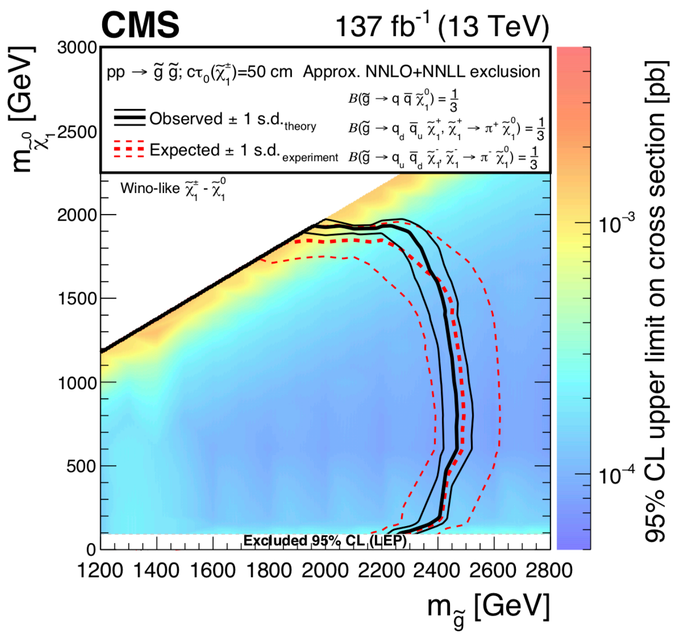
Disappearing tracks with M_{T2}

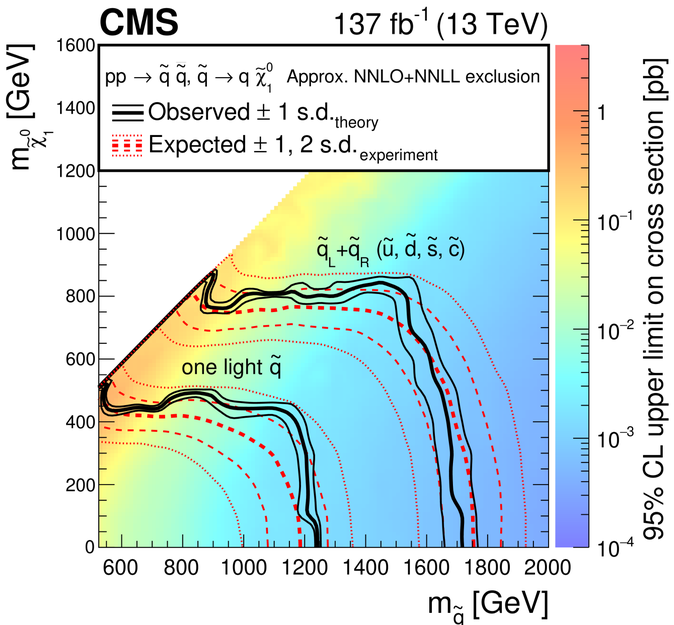
CMS SUS-19-005 (137 fb^{-1})

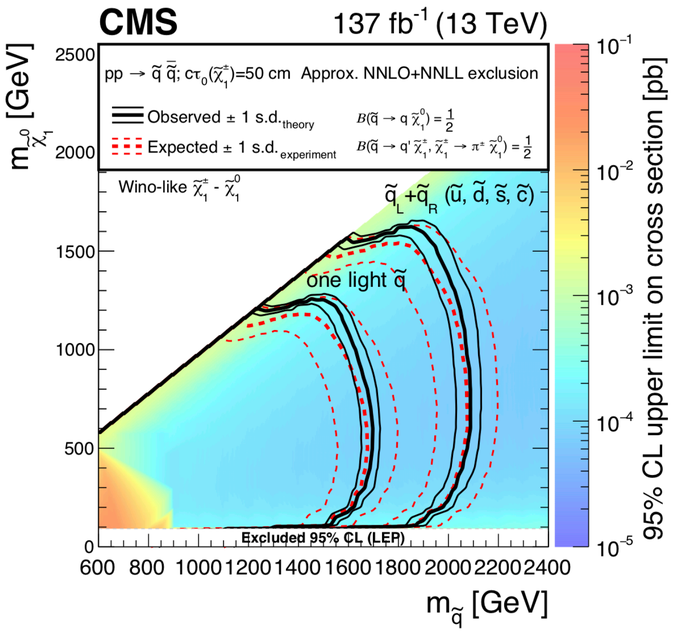
Effect of extending the inclusive M_{T2} search with disappearing track signatures on gluino pair production:

- m_{gluino} reach from ~2 to 2.46 TeV.
- $m_{neutralino}$ reach from ~1.2 to ~2 TeV.
- Significantly improves sensitivity in the compressed region.









Effect of extending the inclusive M_{T2} search with disappearing track signatures on squark pair production:

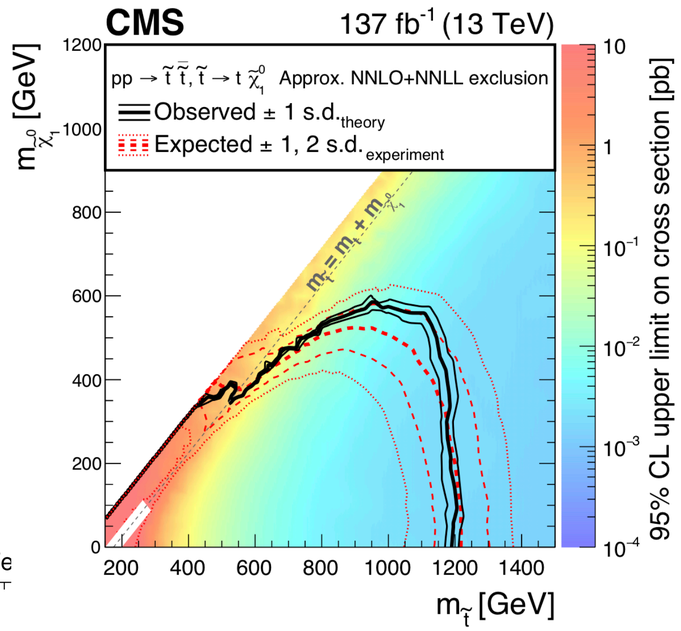
- m_{squark} reach from ~1.8 to ~2.1 TeV.
- $m_{neutralino}$ reach from ~0.8 to ~1.6 TeV.
- Significantly improves sensitivity in the compressed region.

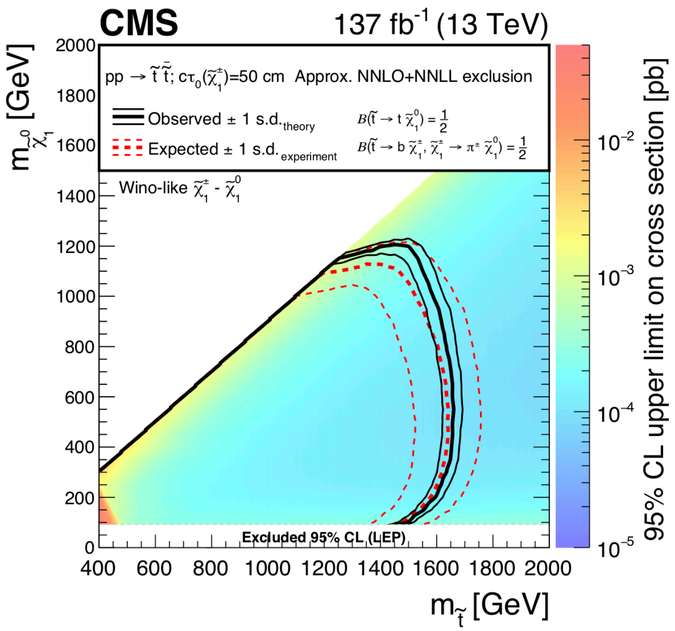
Disappearing tracks with M_{T2}

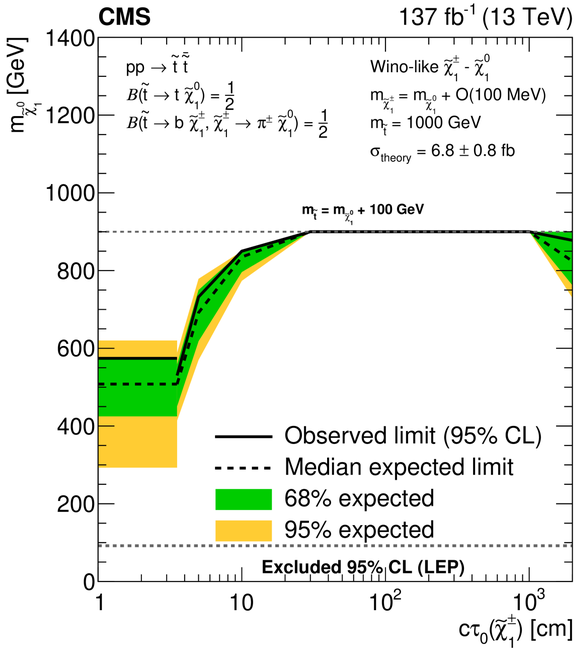
CMS SUS-19-005 (137 fb^{-1})

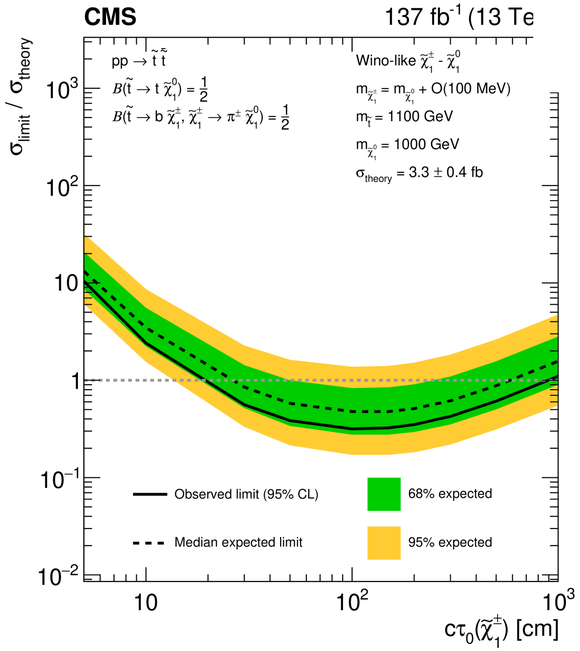
Effect of extending the inclusive M_{T2} search with disappearing track signatures on stop pair production:

- m_{gluino} reach: from ~1.2 to ~1.65 TeV.
- $m_{neutralino}$ reach: from ~0.55 to ~1.25 TeV.
- Significantly improves sensitivity in the compressed region.









For m_{stop} = 1TeV, exclusion limits of

- $m_{chargino}$ as function of chargino decay length
- σ/σ_{theory} as a function of chargino decay length.

Other relevant CMS searches

Earlier searches focusing on non-standard signatures:

- SUS-18-002: Search for SUSY with b jets and photons (2016)
- SUS-18-006: Search for SUSY with H → gg using razor and MT2 variables (2016+2017)
- SUS-17-002: Search for staus (semileptonic) (2016)
- SUS-17-003: Search for staus (hadronic) (2016)
- SUS-17-006: Search for E_T^{miss} and boosted Higgs to bb (2016)
- SUS-17-007: Search for SUSY in VBF (2016)
- SUS-17-008: Search for RPV smuons (2016)
- SUS-17-009: Search for selectrons and smuons (2016)
- SUS-17-011: Search for SUSY in diphoton and E_T^{miss} (2016)
- SUS-17-012: Search for SUSY in photon, lepton and E_T^{miss} (2016)

Summary

Inclusive / stop / leptonic SUSY searches are increasingly supplemented by searches dedicated to specific scenarios / exclusive signatures.

This talk presented 3 recent examples from CMS.

- A boosted ZZ + p_T^{miss} search extended the gluino mass reach to 1.9 TeV for Δm(gluino - N2) = 50 GeV.
- A soft tau + p_T^{miss} + ISR jet search for compressed staus motivated by dark matter coannihilation models obtained the best sensitivity for charginos, surpassing LEP.
- Adding search regions with disappearing tracks to the inclusive hadronic M_{T2} search increased gluino / squark / stop mass limits by 400-600 GeV and significantly improved sensitivity in the compressed region.

Other dedicated searches were performed earlier and more are on the way to explore SUSY further

- Stay tuned for soft opposite-sign 2 leptons; stealth/RPV stops; …