
Searches for SUSY particles (electroweakinos, top squarks and sleptons) from CMS

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(on behalf of CMS Collaboration)

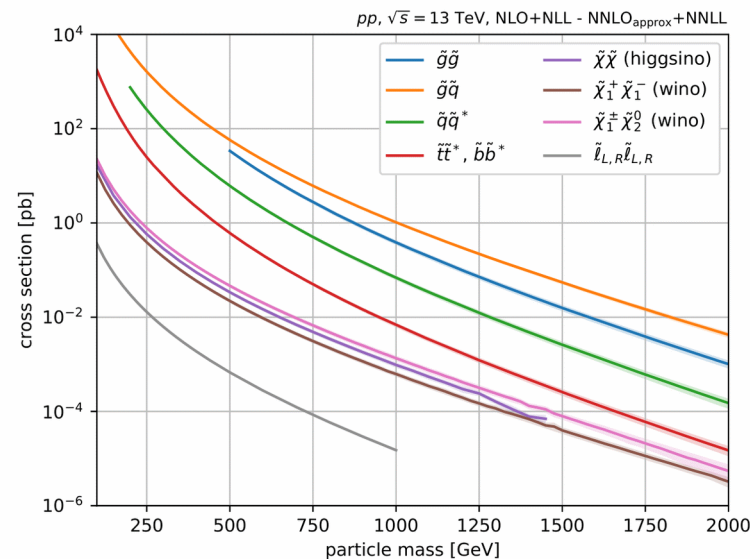
**LP2023: 31st International Symposium on Lepton Photon
Interactions at High Energies**

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Introduction

- Stringent limits on gluinos production at TeV scale leave open promising unconstrained regions for EW searches
- Full CMS Run 2 dataset with 138 fb^{-1} at 13 TeV can significantly extend reach of previous searches
- Lightest SUSY particle (LSP) can be consistent with observed relic dark matter (DM) density in R-Parity conserving scenarios
- Strategies and results from three analysis:
 - Search for top squarks decaying via the four-body decay mode in single-lepton final states (**SUS-21-003**)
 - Search for disappearing tracks (**SUS-21-006**)
 - EWKino Combination: Combined search for electroweak production of winos, binos, higgsinos, and sleptons (**SUS-21-008**)

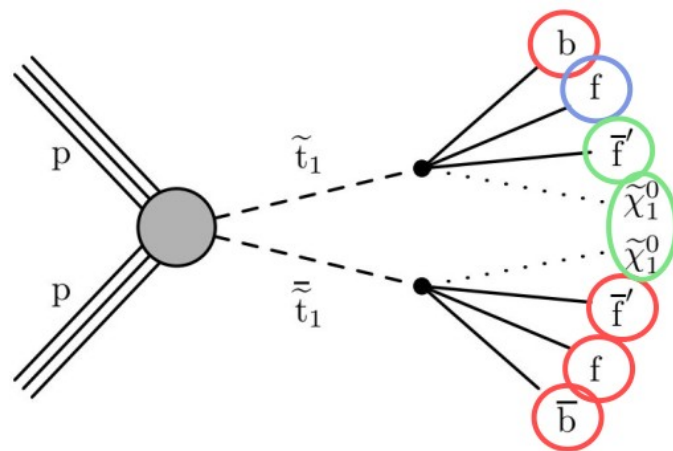


Search for top squarks decaying via the four-body mode in single-lepton final states

SUS-21-003

Search for top squarks decaying via the four-body mode

- Search: 4-body decay of \tilde{t}_1 possible lightest squark
- 2 & 3-body decays of stop are suppressed
- Using MVA for the difficult kinematic region: $\Delta m = m(\tilde{t}_1) - m(\tilde{\chi}_1^0) < m(W)$



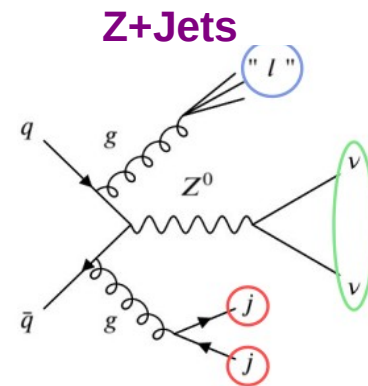
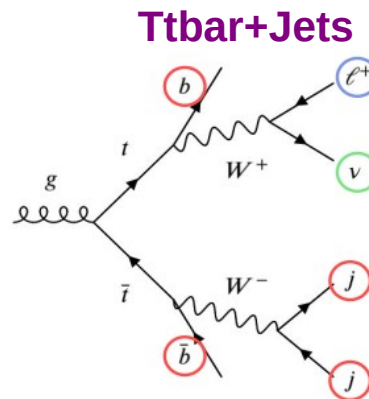
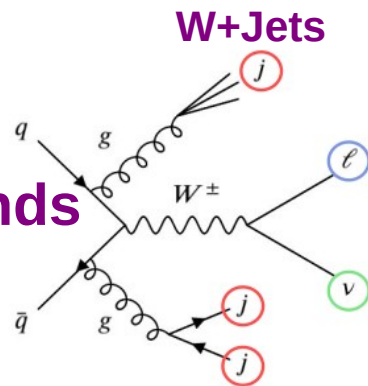
Signature:

1 lepton +

jets +

MET

Standard Model Backgrounds



Data Driven prediction based on the MVA and VRs

Data Driven for fake-lepton prediction

Search for top squarks decaying via the four-body mode

Object Reconstruction

- **Electrons** Lepton
 - $p_T > 5 \text{ GeV}; |\eta| < 2.5$
- **Muons**
 - $p_T > 3.5 \text{ GeV}; |\eta| < 2.4$
- $\text{ISO}_{\text{abs}} < 5 \text{ GeV} \parallel \text{ISO}_{\text{rel}} < 0.2$
- $|d_{xy}| < 0.02; |d_z| < 0.1$

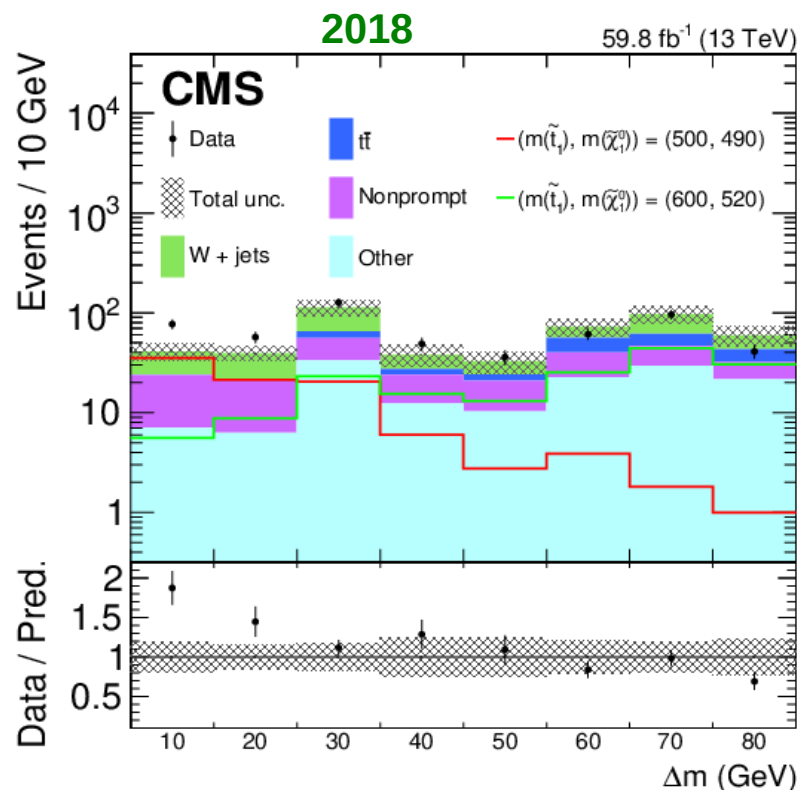
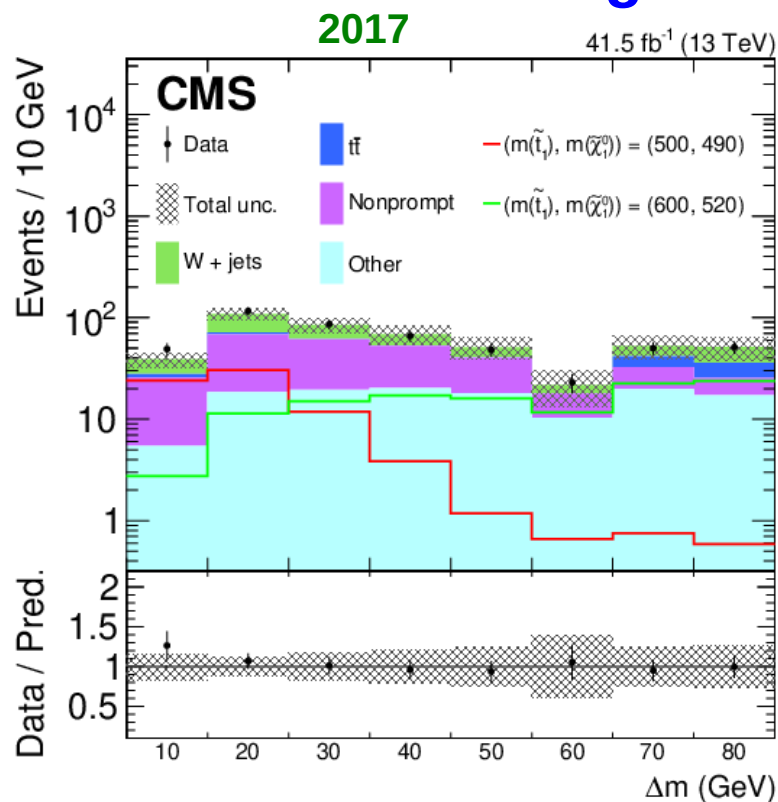
- $p_T > 30 \text{ GeV}$ Jets
- $|\eta| < 2.4$

Preselection

- Exactly 1 lepton
 - Suppress $T\bar{T}$ BG with 2ℓ
- Lepton $p_T < 30 \text{ GeV}$
 - For $\Delta m \leq 60 \text{ GeV}$
- $H_T > 200 \text{ GeV}$
 - Suppress $W+\text{Jets}$ BG
- $p_T(j_1) > 110 \text{ GeV}$
 - prefer signal when high p_T jet from ISR leads to a boost of the sparticle pair
- $\Delta\phi(j_1, j_2) < 2.5$ if $p_T(j_2) > 60 \text{ GeV}$
 - Suppress Multijet background
- $\text{MET} > 280 \text{ GeV}$
 - Neutralinos escape as MET

Search for top squarks decaying via the four-body mode

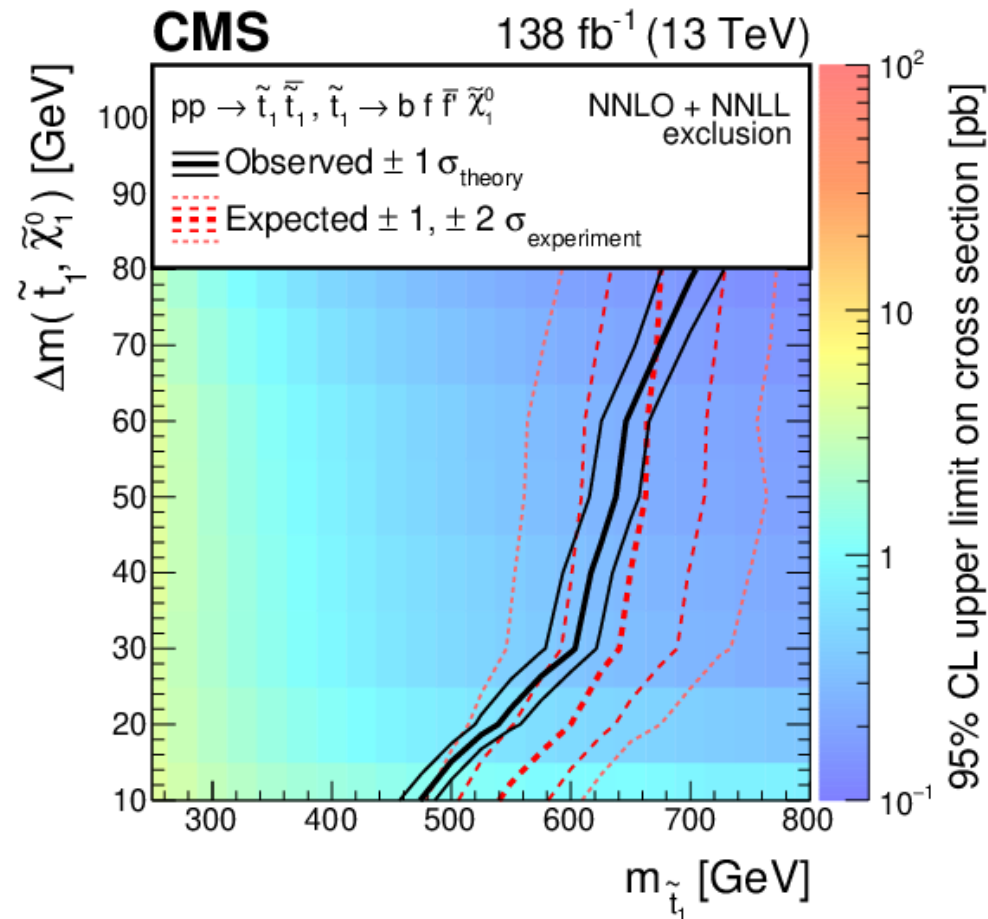
Signal Region distribution



No significant excesses are found, hence there is no evidence for direct top squark production

Search for top squarks decaying via the four-body mode

Full Run 2 Combined Limits



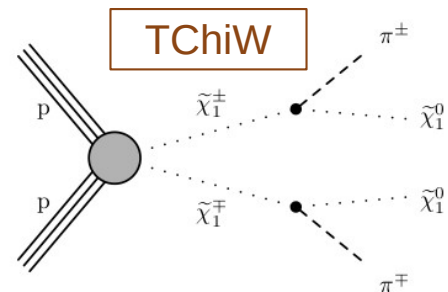
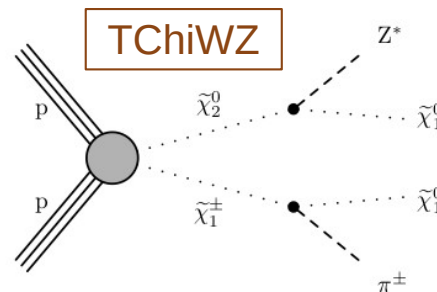
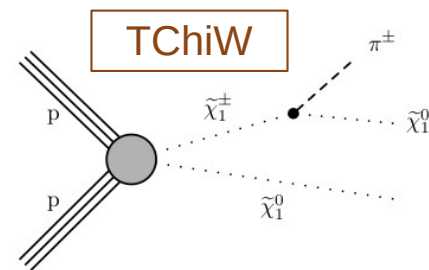
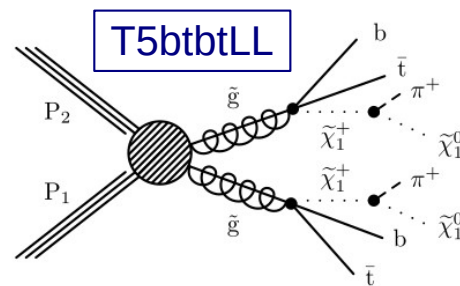
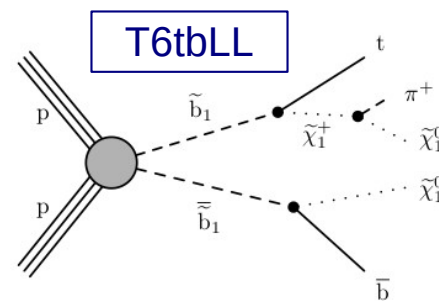
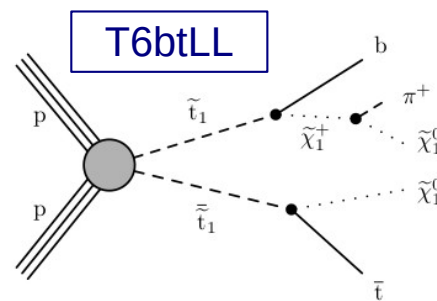
The limits of the previous analysis are significantly improved. At low (high) Δm the top squark mass exclusion limit is 60 (140) GeV higher.

Search for disappearing tracks

SUS-21-006

Search for disappearing tracks

- Compressed SUSY with $\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) \sim \mathcal{O}(100 \text{ MeV})$
 - $\tilde{\chi}_1^\pm$ is long lived.
 - decays inside tracker to a soft undetectable $\pi^\pm + p_{\text{Tmiss}}$
 - disappearing track (DTk) signature.
- 1 / ≥ 2 disappearing track + $p_{\text{Tmiss}} + \geq 1$ jet + 0/1 lepton:
 - Target long-lived $\tilde{\chi}_1^\pm$ from strong or EWK production.



Search for disappearing tracks

Categories	Track preselection
short - only pixel hits	$p_{T,\text{short}} > 25 \text{ GeV}, \eta < 2.0$
long - pixel and strips hits	$p_{T,\text{long}} > 40 \text{ GeV}, \eta < 2.0$

**Track selection/
categorization**

Channels	Baseline Selections
≥ 1 DTk, 0 lepton	hard MET > 150 GeV, ≥ 1 jets
≥ 1 DTk, ≥ 1 electron	≥ 1 jet, $m_T > 100$, $m_{L_t} > 140 \text{ GeV}$
≥ 1 DTk, ≥ 1 muon	≥ 1 jet, $m_T > 100$, $m_{L_t} > 140 \text{ GeV}$

Event selection

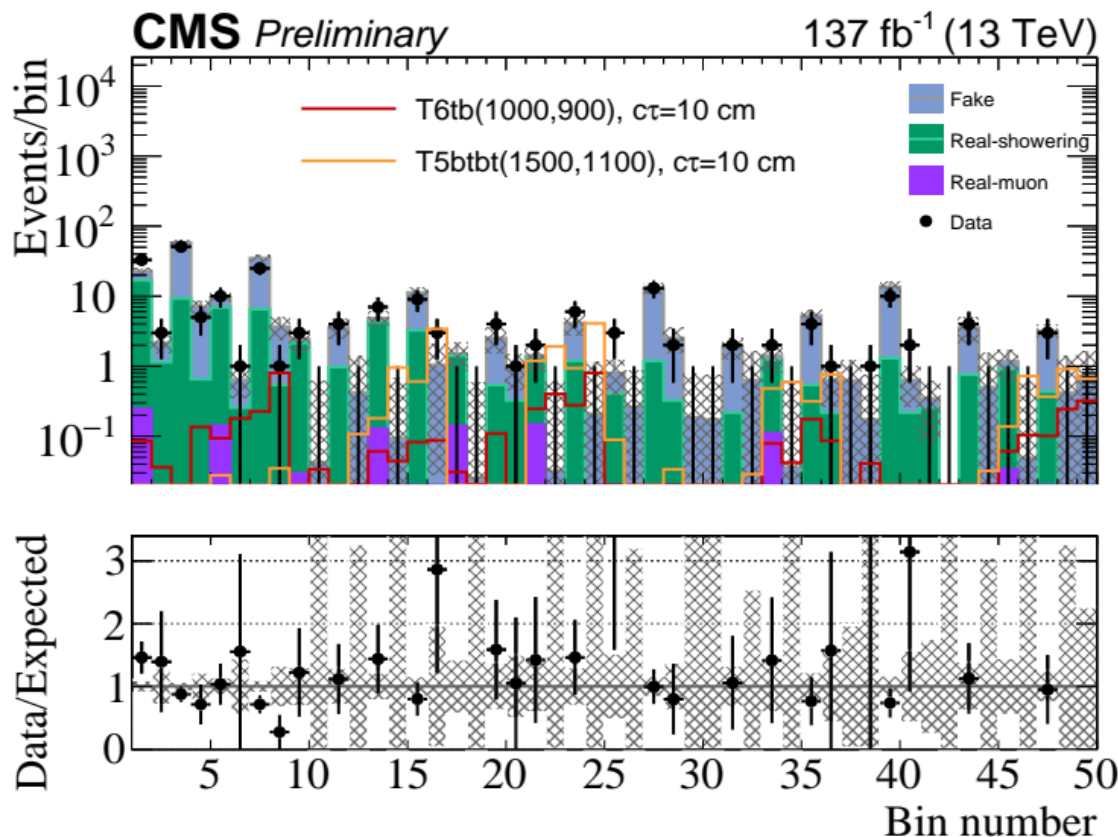
Backgrounds: 1) Hadrons and leptons poorly reconstructed in tracker;
2) tracks built out of the coincidental alignment of hits from different tracks.

Background estimation: Data-driven method.

Calculate transfer factors in sideband regions and apply to DTk candidates in control regions.

Search for disappearing tracks

Signal Region distribution

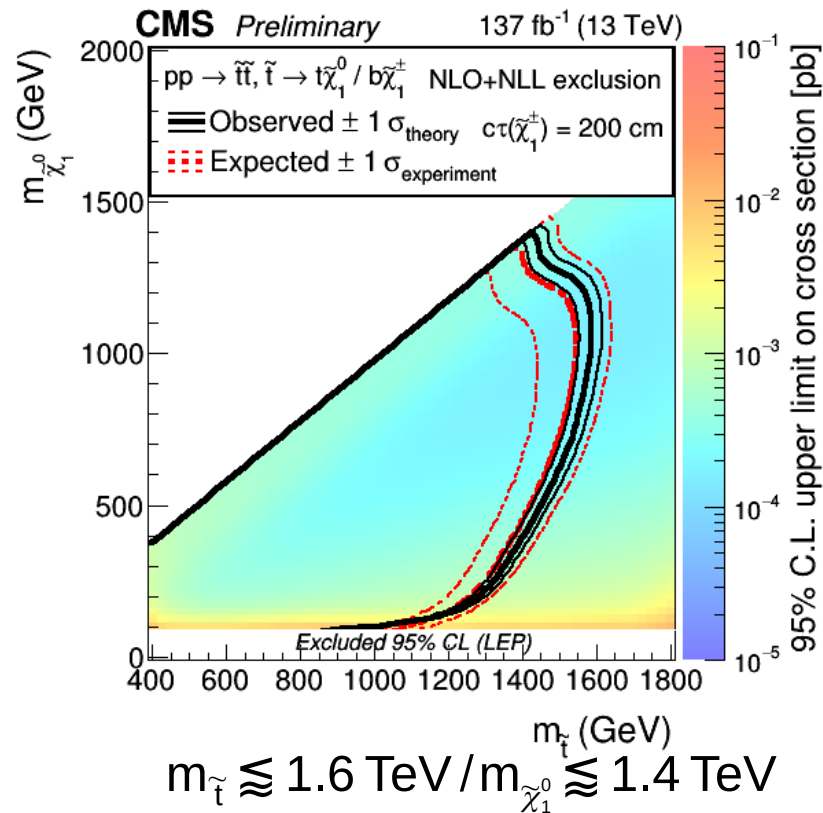
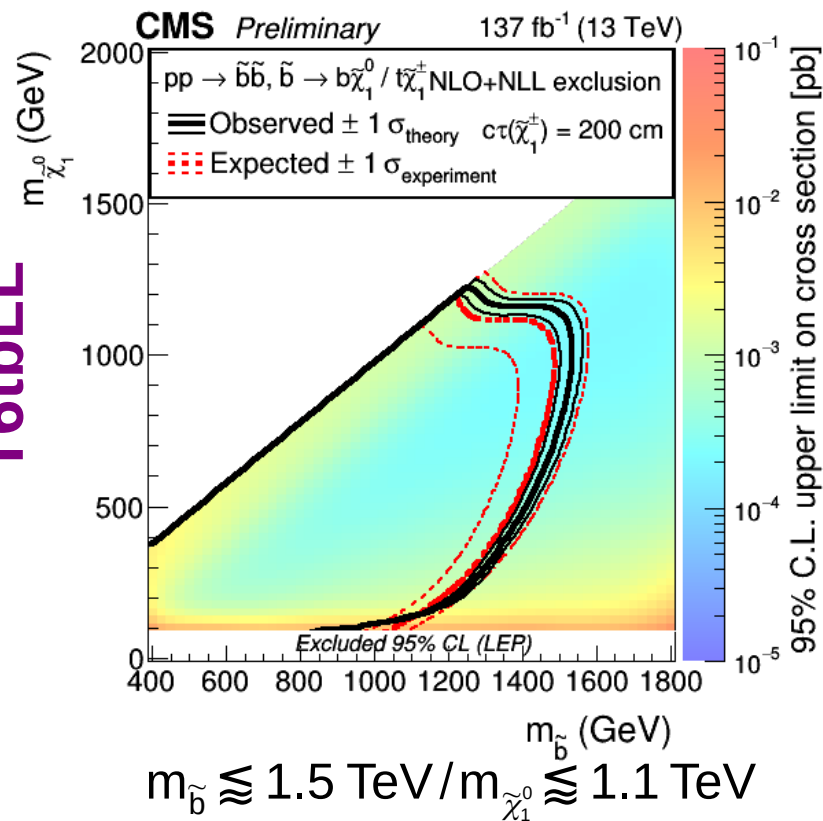


- Comparison between the data and SM background predictions for the 49 signal regions.
- No statistically significant excess observed in a single SR

Search for disappearing tracks

Upper limits on the cross section

T6tbLL

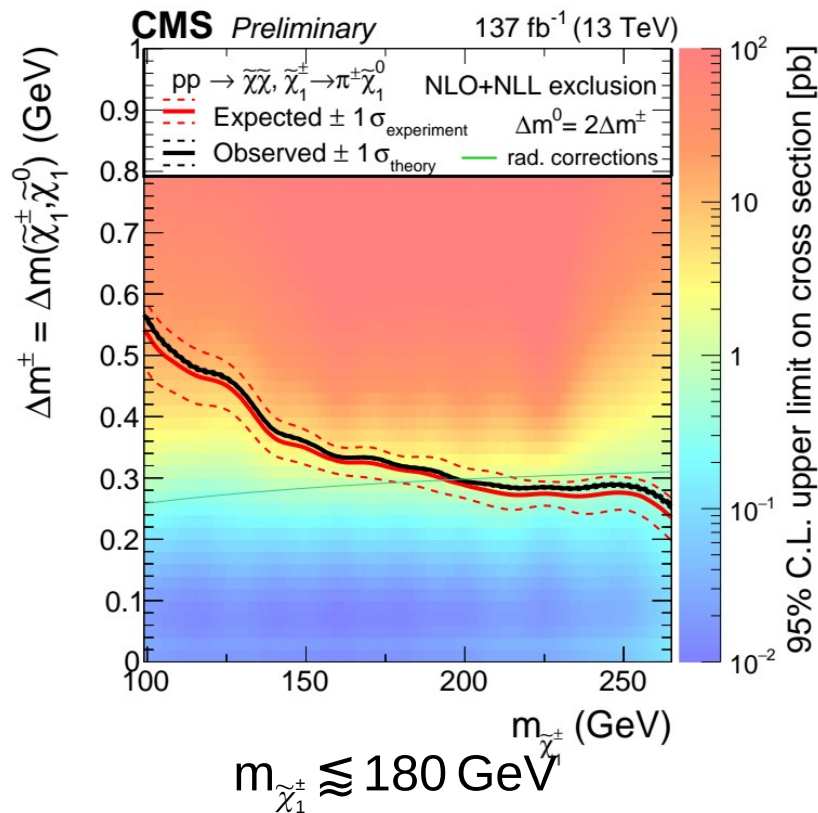
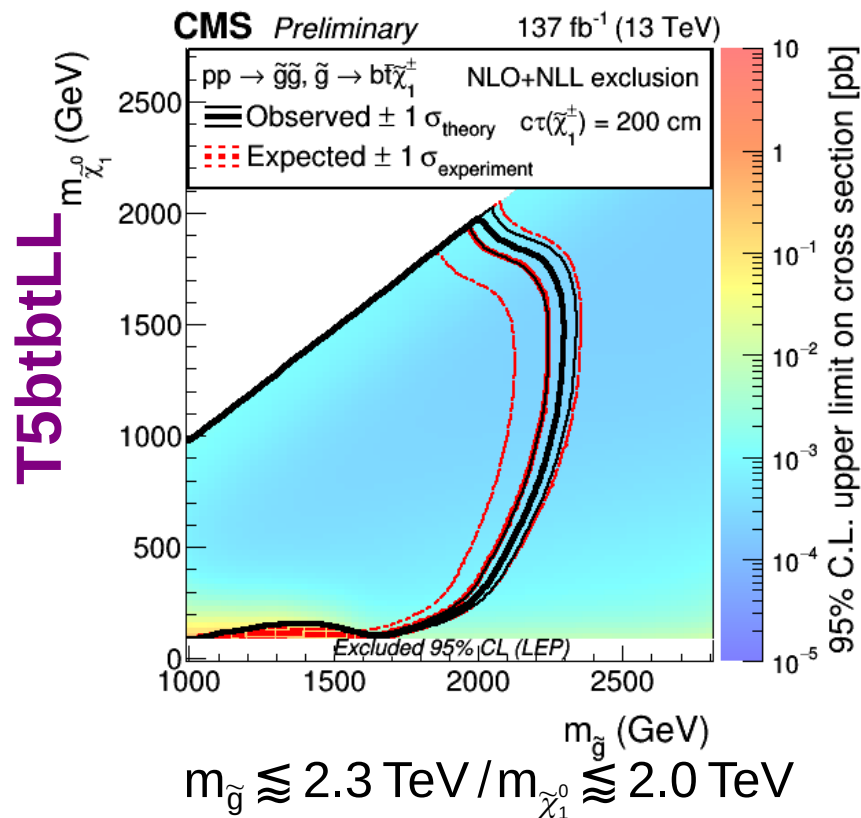


T6btLL

Up to ~500 GeV $\tilde{\chi}_1^\pm / \tilde{\chi}_2^0$ mass improvement in the compressed region wrt. prompt searches

Search for disappearing tracks

Upper limits on the cross section



Up to $\sim 200 \text{ GeV}$ $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ mass improvement in the compressed region wrt. previous DTK search

Combined search for electroweak production of winos, binos, higgsinos and sleptons

SUS-21-008

Combined EWKino searches

Ideal for compressed scenarios

Ideal for (semi) compressed scenarios

SUS-18-004 (SOS)

“2/3l soft”

Two or three e (mu),
Opposite-sign, same-flavour pair
 $5(3.5) < \text{lepton } p_T < 30 \text{ GeV}$

SUS-19-012 (ML)

“ $\geq 3l$ ”

Three or four leptons
(up to 2 hadronically decaying taus)
or two same-sign light leptons
Leading lepton $p_T > 30 \text{ GeV}$ (3l)

SUS-20-001 (zedge)

“2l on-Z/non-resonant”

Two e(mu)
Opposite-sign, same-flavour
pair
Either on-shell or off-shell Z

SUS-20-003

“1l2b” - WH

One e(mu), $H \rightarrow b\bar{b}$

SUS-20-004

“4b” - HH

No leptons
Two Higgs bosons; $H \rightarrow b\bar{b}$

SUS-21-002

“Hadr. WX”

Fully hadronic final state;
at least 2 jets (AK8),
and 2-6 jets (AK4)

Ideal for (semi) large mass splitting

Ideal for large mass splitting

Advanced jet reconstruction techniques help isolate signal from top & W/Z+jets backgrounds

Combined EWKino searches

Compressed region:

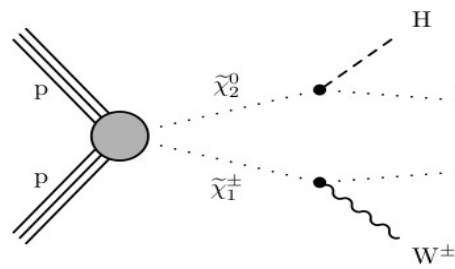
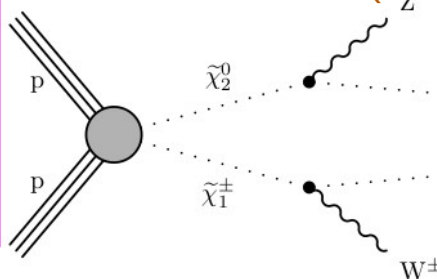
New parametric signal extraction optimizes binning for different Δm :
Improvements as large as 30 GeV

CMS-SUS-18-004 (2/3l soft)

CMS-SUS-19-012 ($\geq 3l$)

CMS-SUS-20-001 (2l on-Z)

CMS-SUS-21-002 (had. WX)



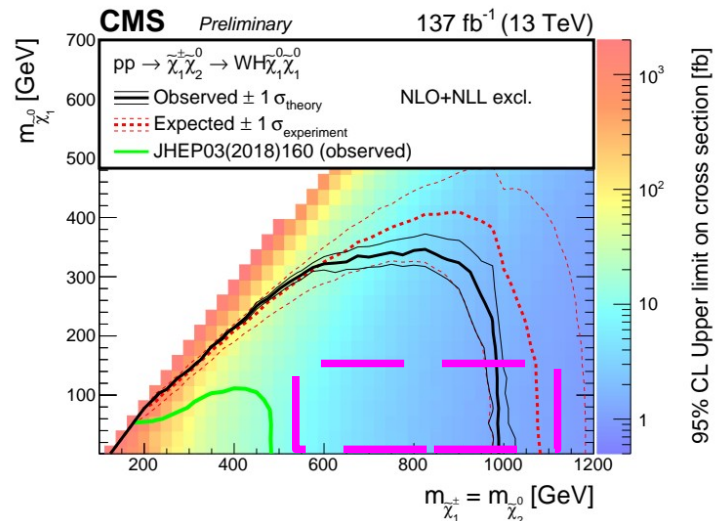
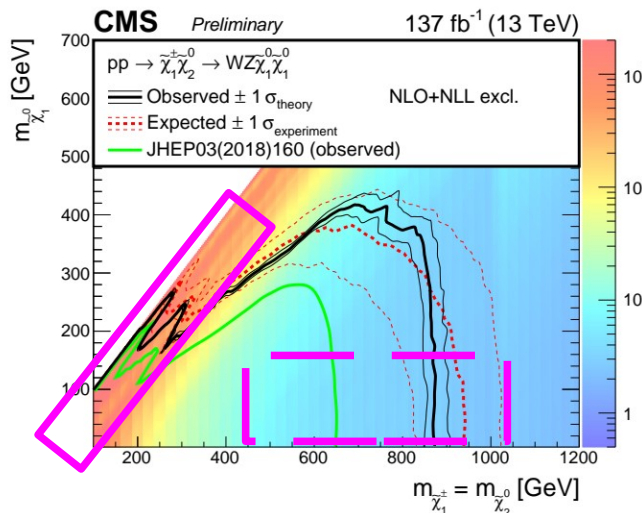
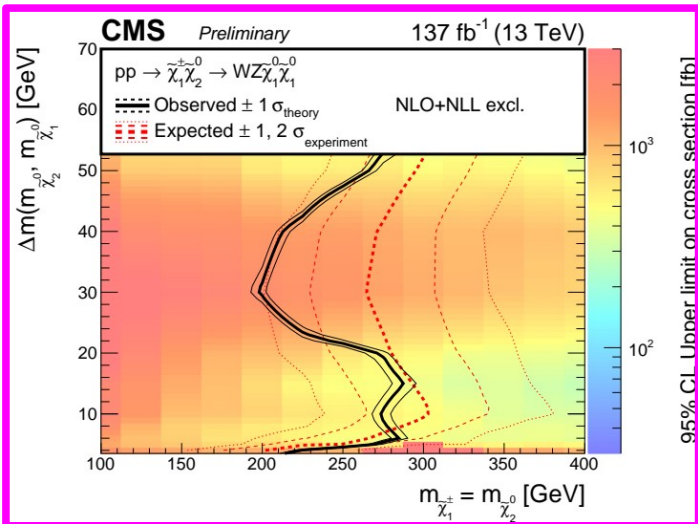
Uncompressed region:

New hadronic probes are adding new sensitivity

CMS-SUS-19-012 (≥ 3)

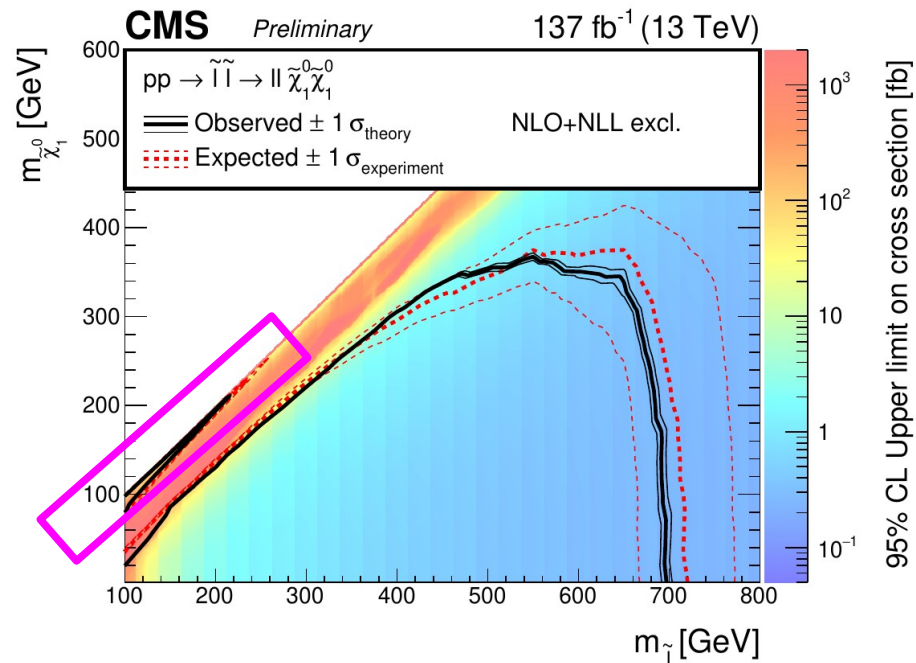
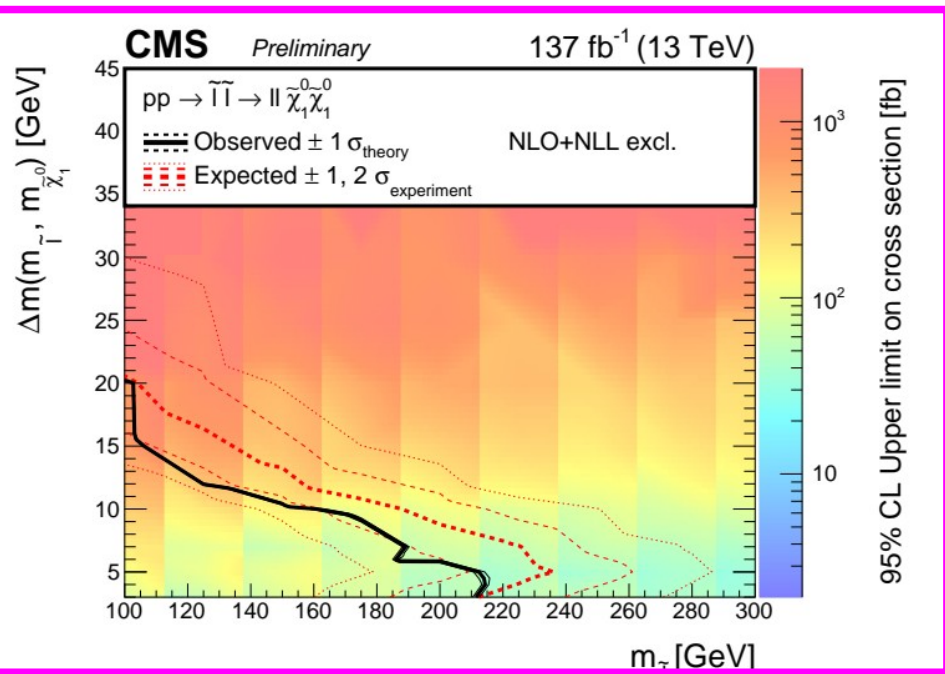
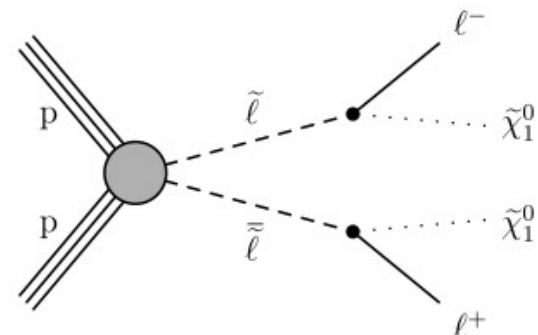
CMS-SUS-20-001 (2 on-Z)

CMS-SUS-21-002 (had. WX)



Combined EWKino searches

- Combination of 2/3l soft lepton & 2l non-resonant search extended to slepton pair production
- Reach slepton masses of ~ 215 GeV at $\Delta m = 5$ GeV



Summary

- CMS continues to explore every corner of the SUSY parameter space.
- Presented 3 most recent results:
 - Search for top squarks decaying via the four-body mode in single-lepton final states with a MVA approach using Full Run II with 138 fb^{-1} at 13 TeV .
 - Disappearing tracks: First LHC search with lepton+disappearing track. Hundreds of GeV sensitivity improvement in the compressed region.
 - EWKino combination: Combined search for electroweak production of winos, binos, higgsinos, and sleptons. Clearly showed sensitivity complementarity of different searches. Motivates further combination studies.
- Exploration continues — With on-going Run 3 more searches are on the way!

Thank You!

Additional Material