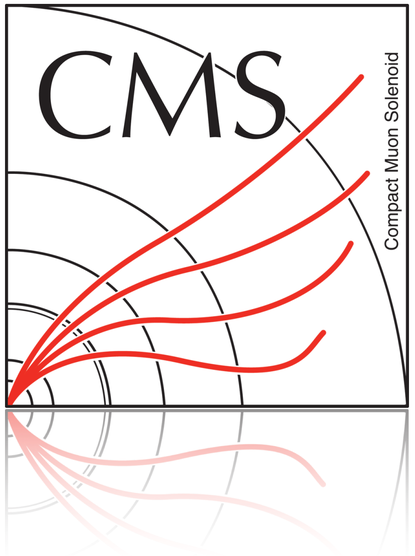
Searches for Supersymmetry with CMS

Valentina Dutta



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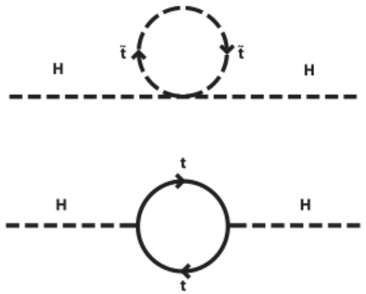
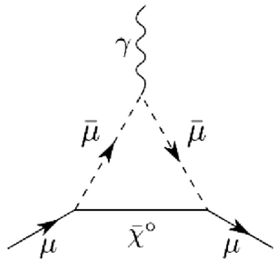
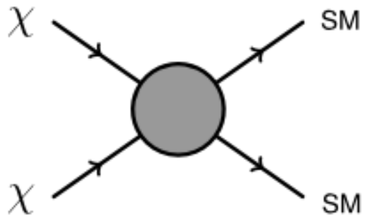
Supersymmetry

Proposes symmetry relating bosons and fermions

- Superpartners could help address various shortcomings with the SM and unanswered questions, e.g. hierarchy problem, $(g\text{-}2)_\mu$, dark matter

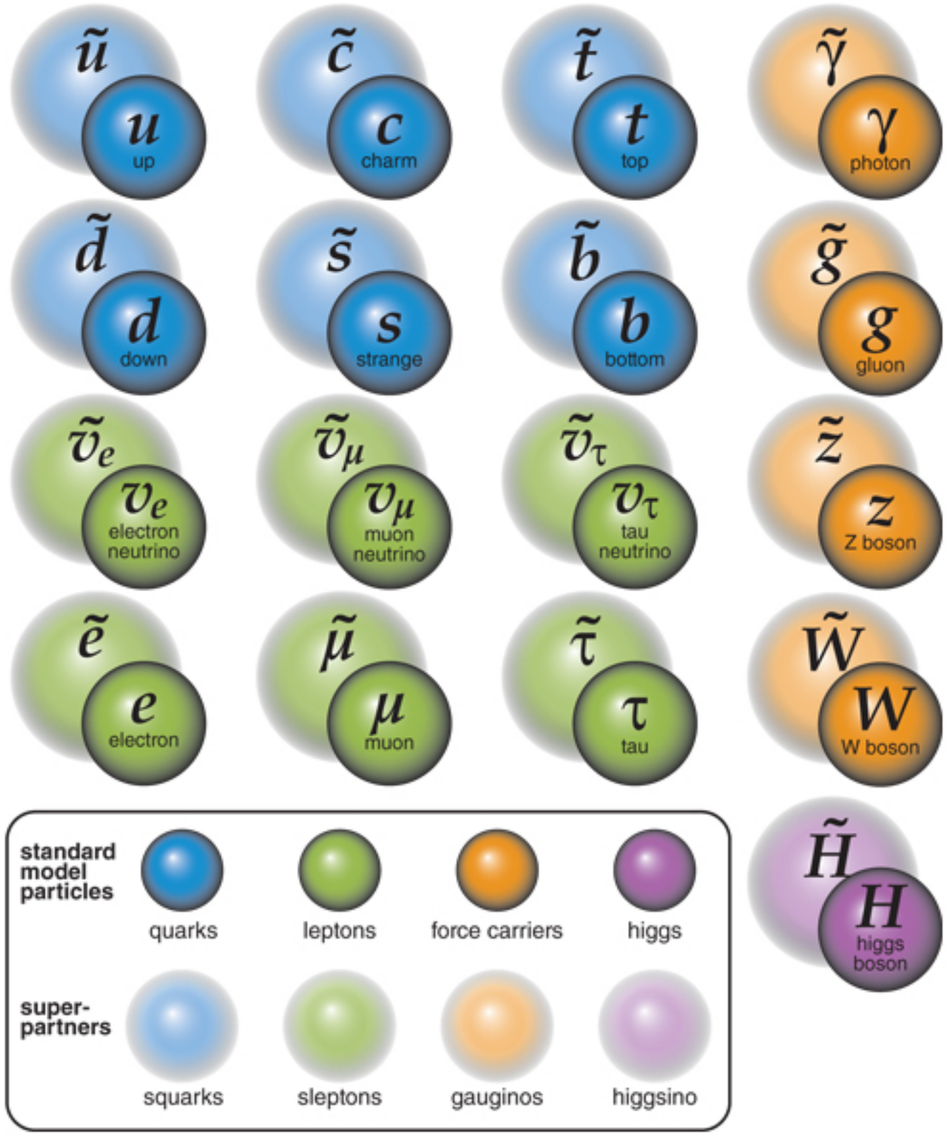




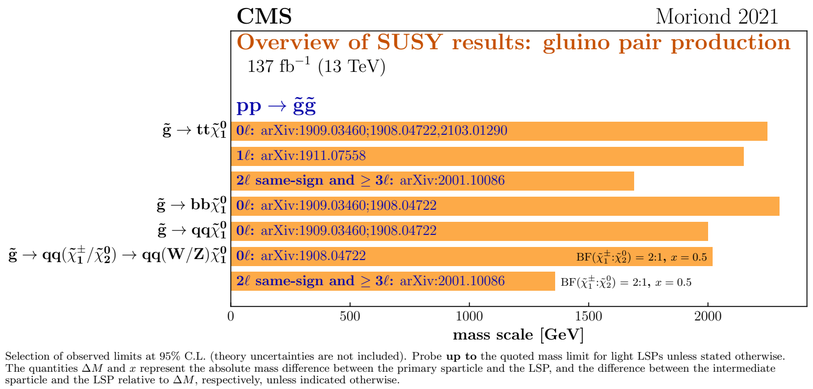


Rich phenomenology depending on mass hierarchy, nature of lightest SUSY particle (LSP), SUSY breaking mechanism, etc.

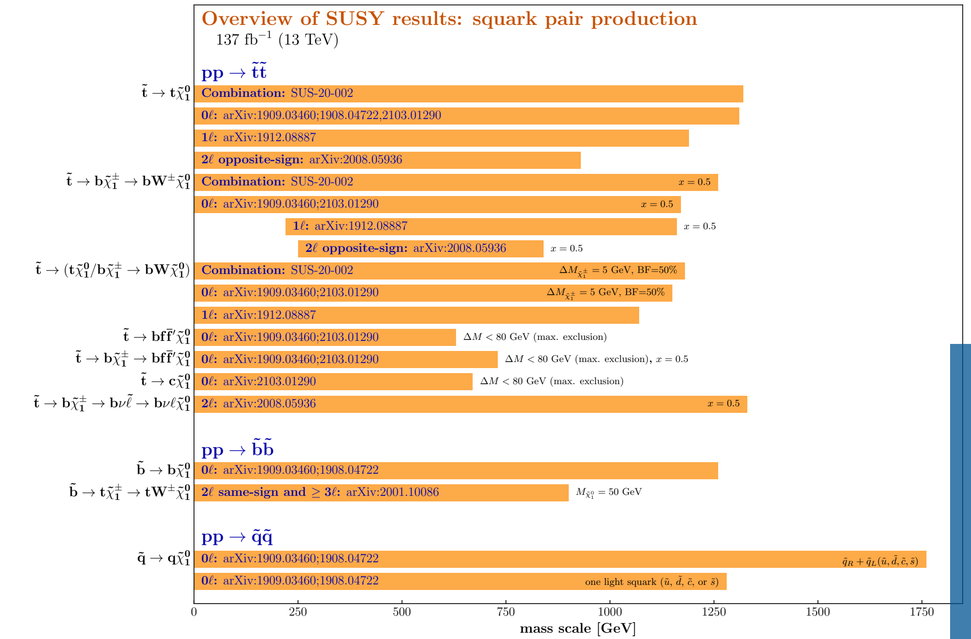
- Many places to search experimentally



The SUSY search program with CMS



Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe **up to** the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM, respectively, unless indicated otherwise.



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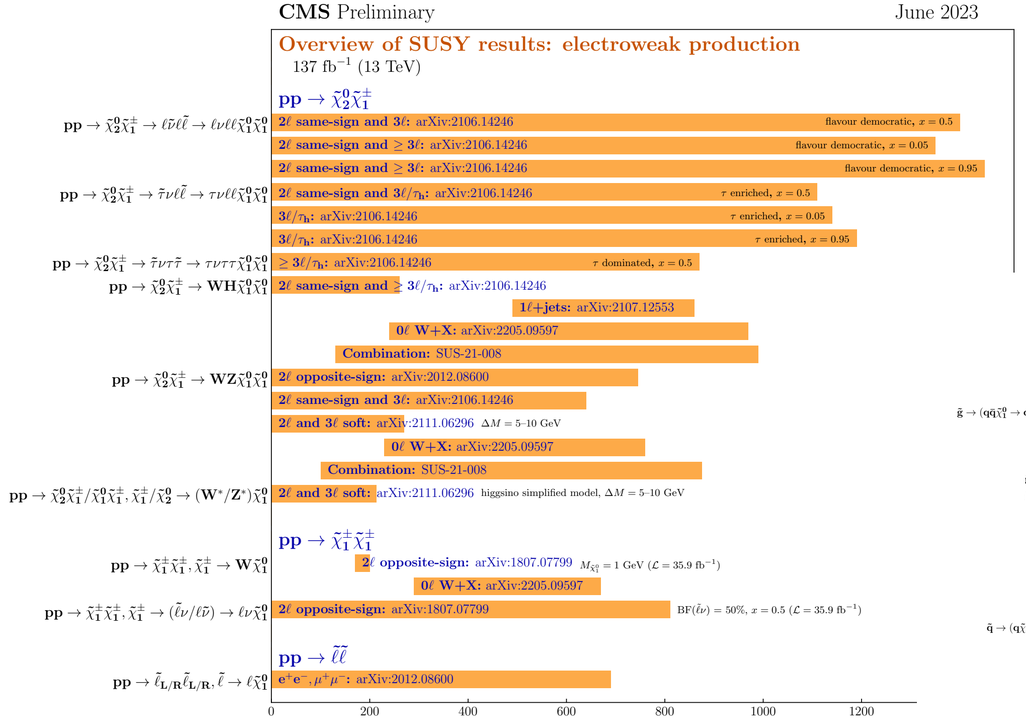

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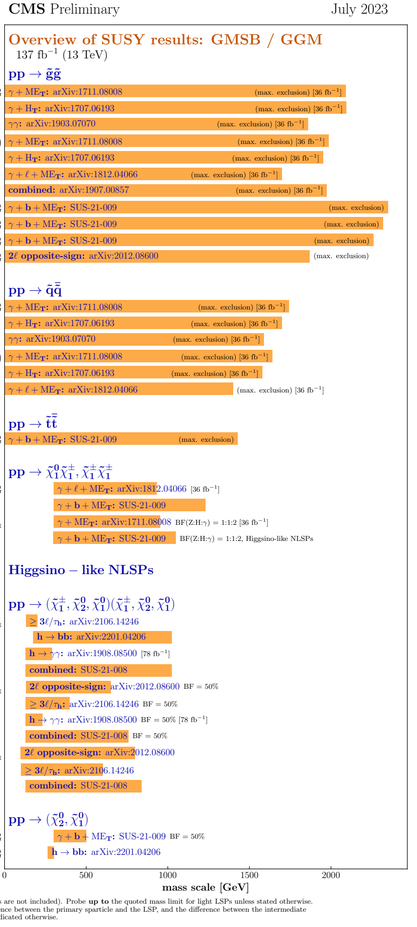

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- Extensive program with large number of searches in different final states completed with LHC Run 2 data
- Most focus on R-parity conserving SUSY: superpartners pair produced, stable LSP produces missing energy signature

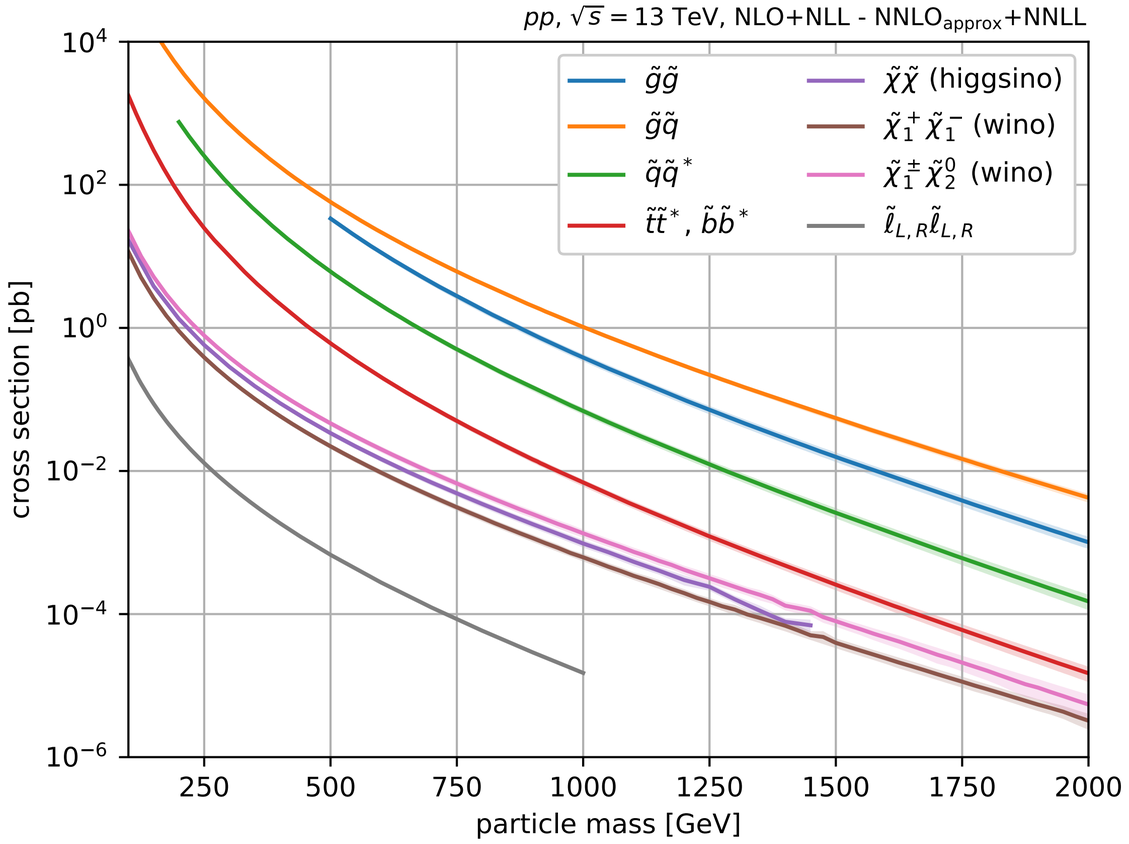
Recent highlights

With the full Run 2 dataset, search program expanded to address variety of scenarios

- More challenging experimental signatures, e.g. low/no missing energy, long-lived particles
- Compressed mass spectra
- Models with small production cross sections, e.g. sleptons

Highlighting a few recent results here

- Combination of electroweak SUSY searches (CMS-SUS-21-008)
- Search for “stealth” SUSY with photons (CMS-SUS-19-001)
- Search for SUSY with “disappearing tracks” (CMS-SUS-21-006)



Combination of electroweak SUSY searches

CMS-SUS-21-008
arXiv:2402.01888

Ideal for compressed scenarios | *Ideal for semi-compressed scenarios*

Leptonic

"2/3l soft"
CMS-SUS-18-004
2-3 low p_T e/μ with opposite-charge same-flavor pair + p_T^{miss}

"≥3l + 2lSS"
CMS-SUS-19-012
Same-charge e/μ pair + p_T^{miss}, or ≥3 leptons + p_T^{miss} with parametric NN

"2l on-Z / non-resonant"
CMS-SUS-20-001
Opposite-charge e/μ pair on- or off-shell Z + p_T^{miss}

Semileptonic or hadronic

"1l 2b (WH)"
CMS-SUS-20-004
e/μ + H→bb + p_T^{miss}, resolved and boosted H(bb) reconstruction

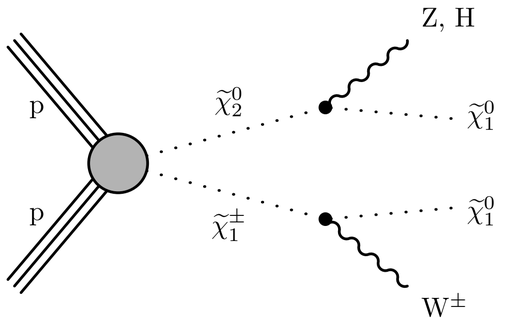
"4b (HH)"
CMS-SUS-19-012
2 H→bb + p_T^{miss}, resolved and boosted H(bb) reconstruction

"Hadronic WX"
CMS-SUS-21-002
Fully hadronic final state + p_T^{miss}, boosted W/Z/H reconstruction

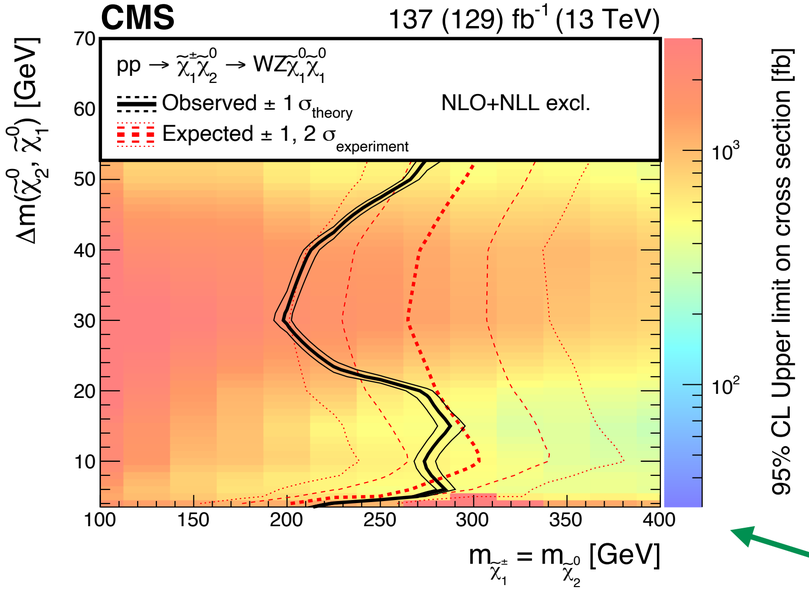
Ideal for (semi) large mass splittings | *Ideal for large mass splittings*

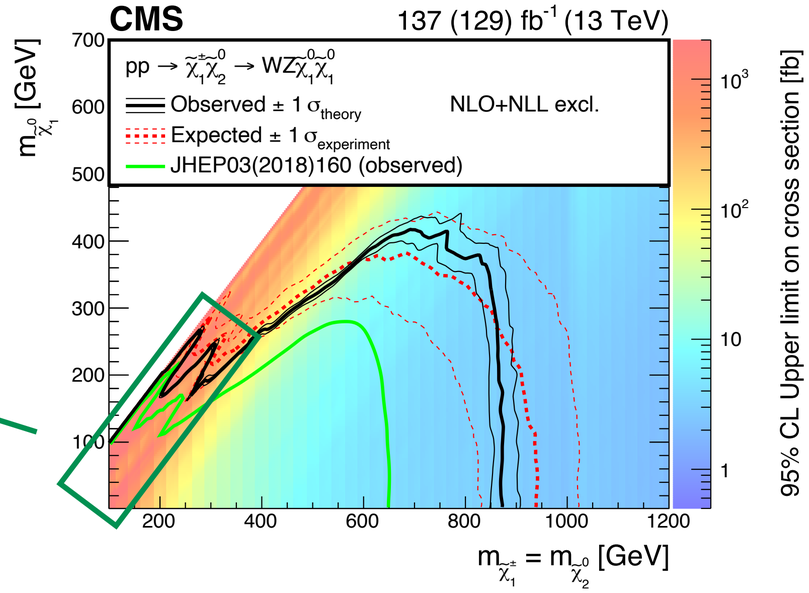
- Lower cross sections for direct production of charginos/neutralinos and sleptons
- Combination of searches benefits from complementarity, improves reach
- Advanced techniques including use of parametric NN for signal extraction, identification of jets from hadronic W/Z/H decays

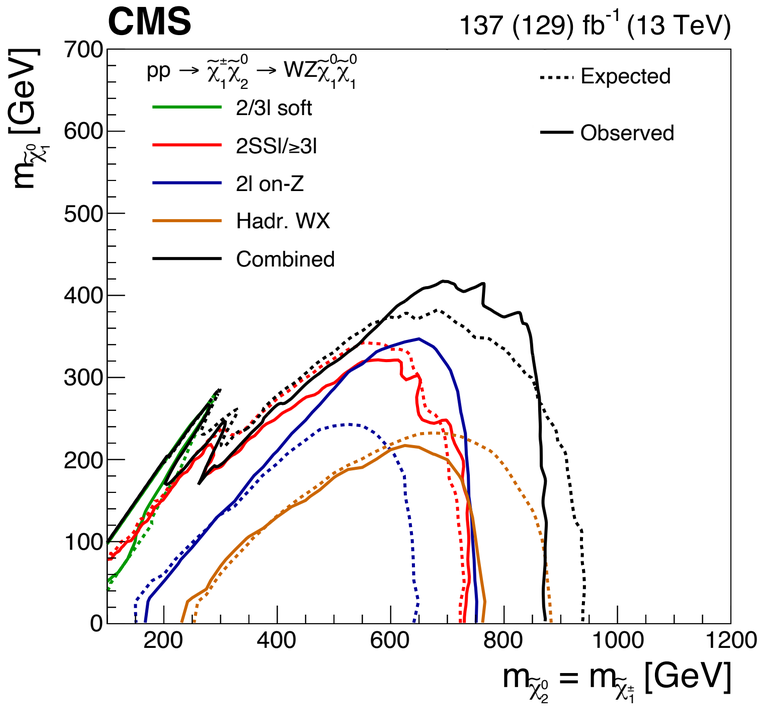
Chargino/neutralino production



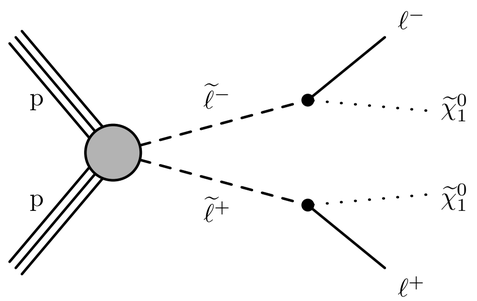
- Complementary sensitivity from **2/3l soft** and **≥3l** searches in **compressed region**, **parametric signal extraction** optimizes binning for different Δm
- **Fully hadronic** states with **boosted W/Z/H** add sensitivity in **uncompressed region**



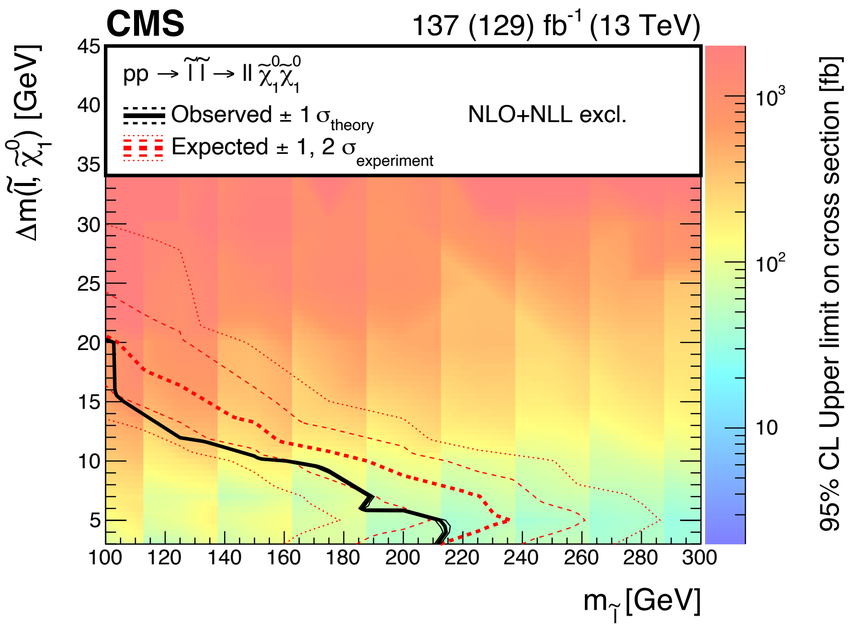


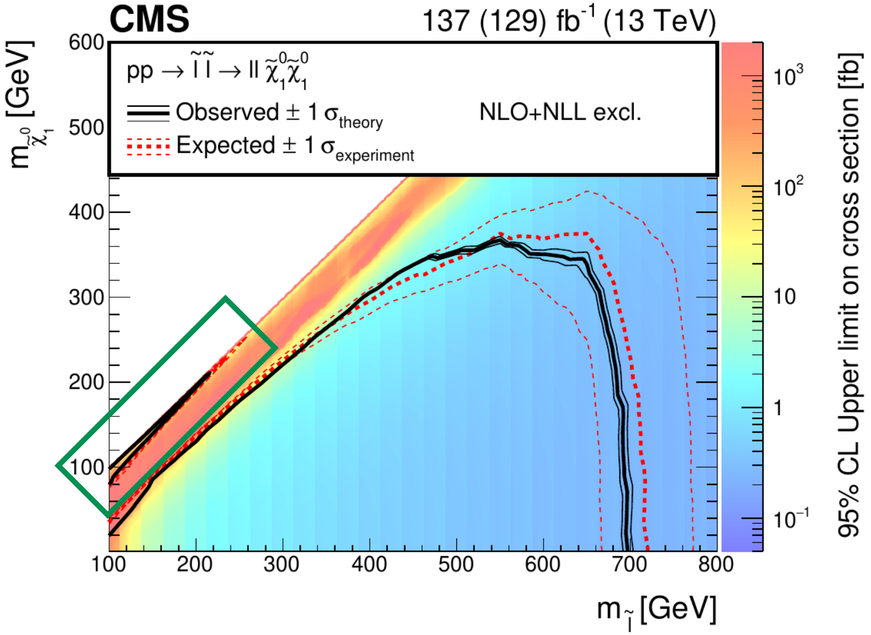


Sleptons



- Challenge from low cross sections
- Assuming degenerate 1st and 2nd generation left- and right-handed sleptons
- **2/3l soft** targets **compressed region**, **2l non-resonant** targets **uncompressed region**



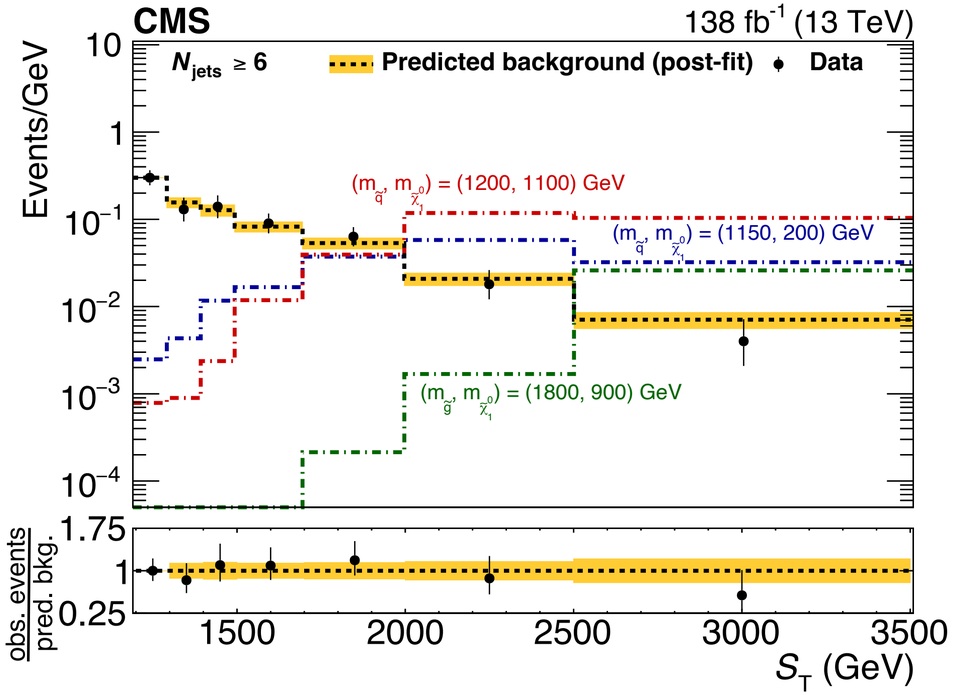


Stealth SUSY with photons

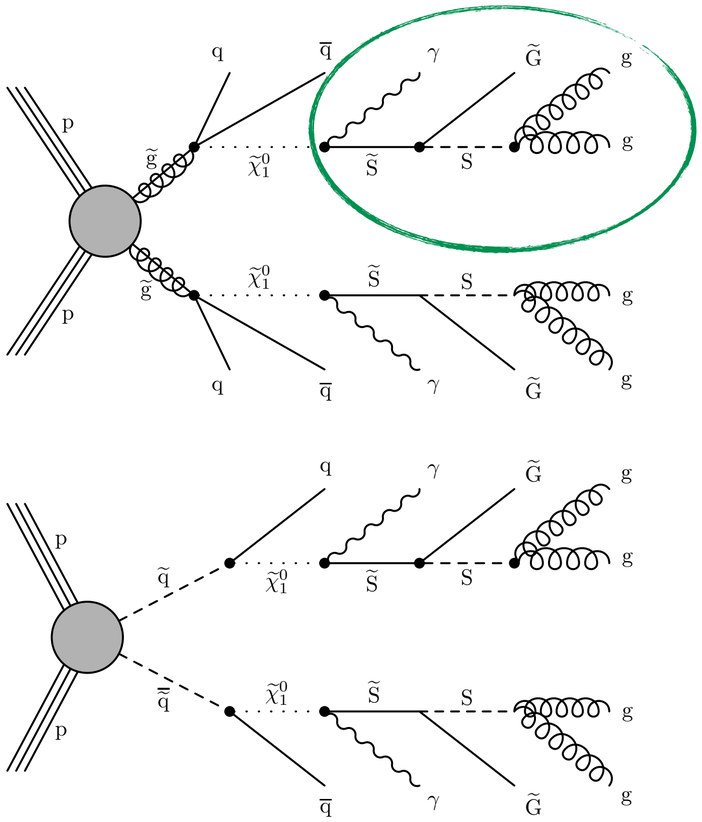
CMS-SUS-19-001

arXiv:2310.03154

- Stealth SUSY: light, weakly coupled hidden sector
- Assume ~mass degenerate **singlet** and **singlino**, with gravitino LSP. **Low p_T^{miss}** signature
- Search for strongly produced stealth SUSY targets final state with **photons + jets**. **S_T** (scalar sum of physics object p_Ts) used as discriminating variable

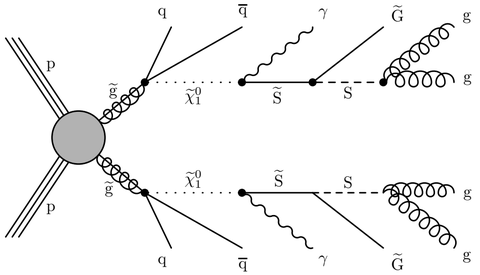


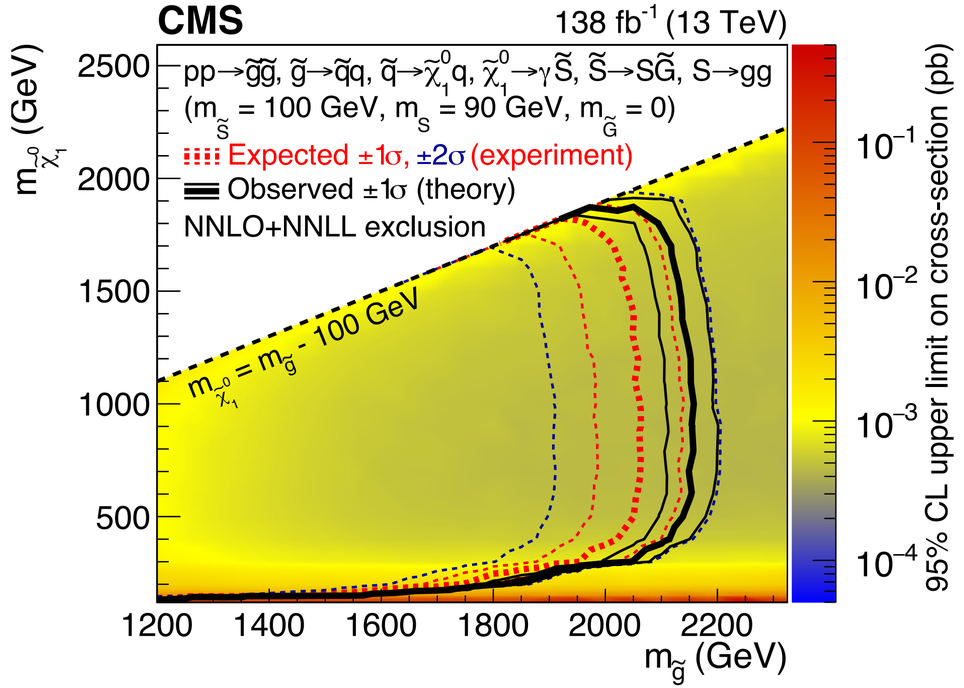
Data-driven background estimation extrapolates S_T shape from low jet multiplicity

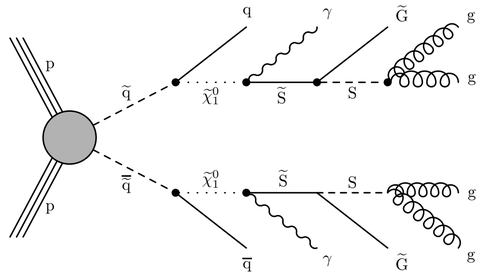


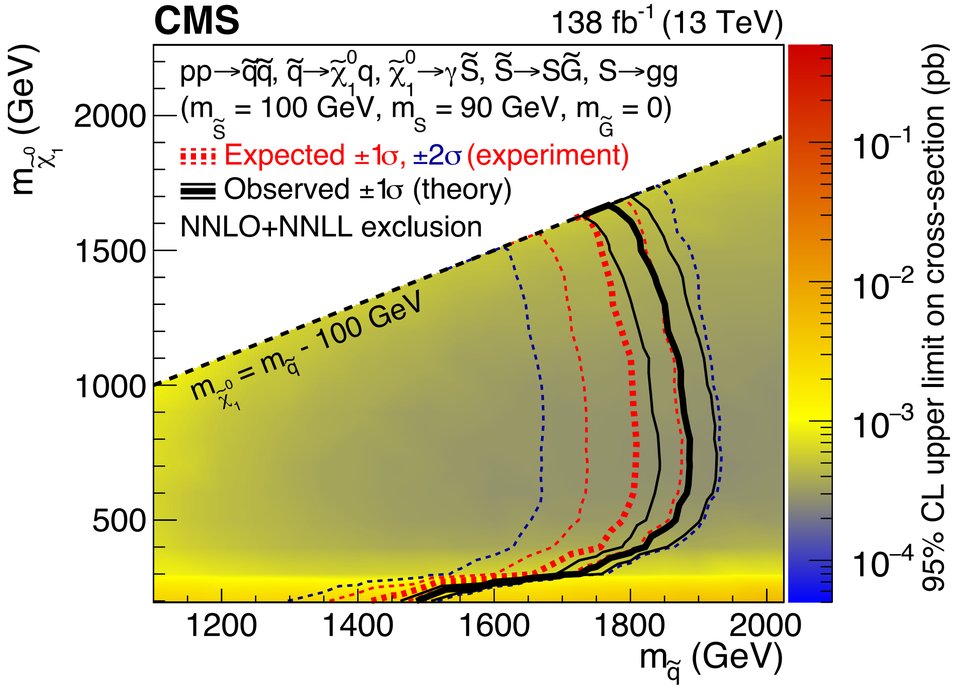
Stealth SUSY with photons: interpretations

Gluino and squark exclusions in simplified models for fixed singlet, singlino, gravitino masses





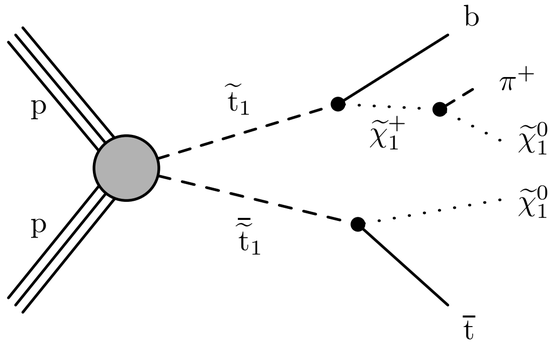


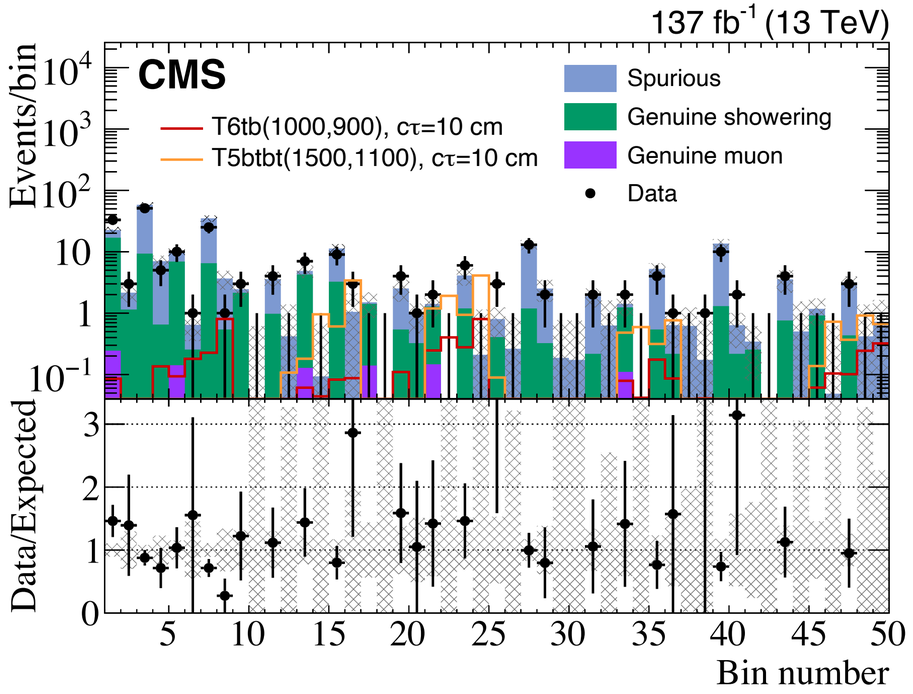


SUSY with disappearing tracks

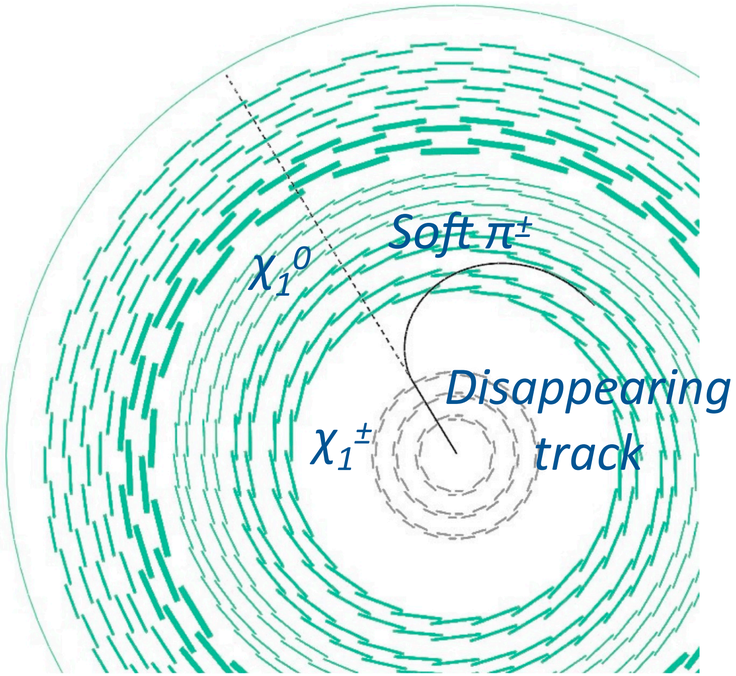
CMS-SUS-21-006
arXiv:2309.16823

- Compressed SUSY with nearly mass degenerate chargino and LSP (Δm ~O(100 MeV) → **long-lived chargino**
- Chargino decays inside tracker to soft undetectable π± + LSP, leading to **"disappearing track" + p_T^{miss}**
- Search targets final state with **≥1 disappearing track, ≥1 jet, 0/1 e/μ + p_T^{miss}** for range of signal models



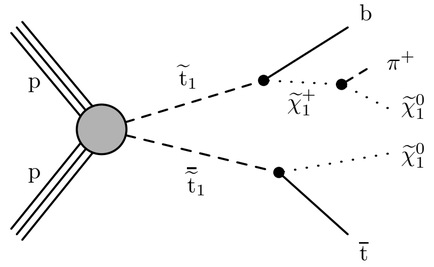


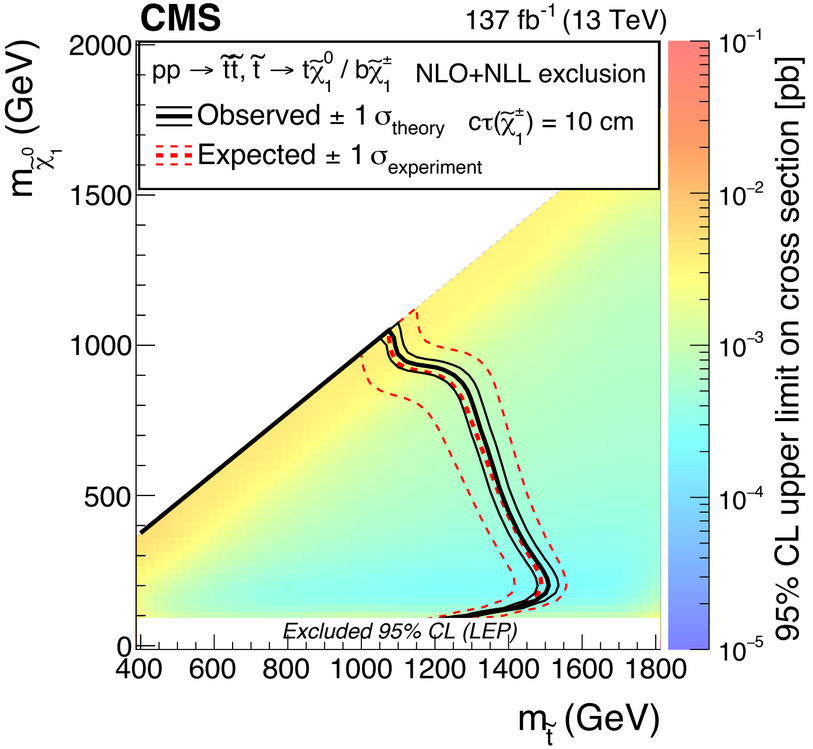
Boosted decision trees used to identify short (pixel-only) and long (pixel+strip) disappearing tracks for **range of lifetimes**

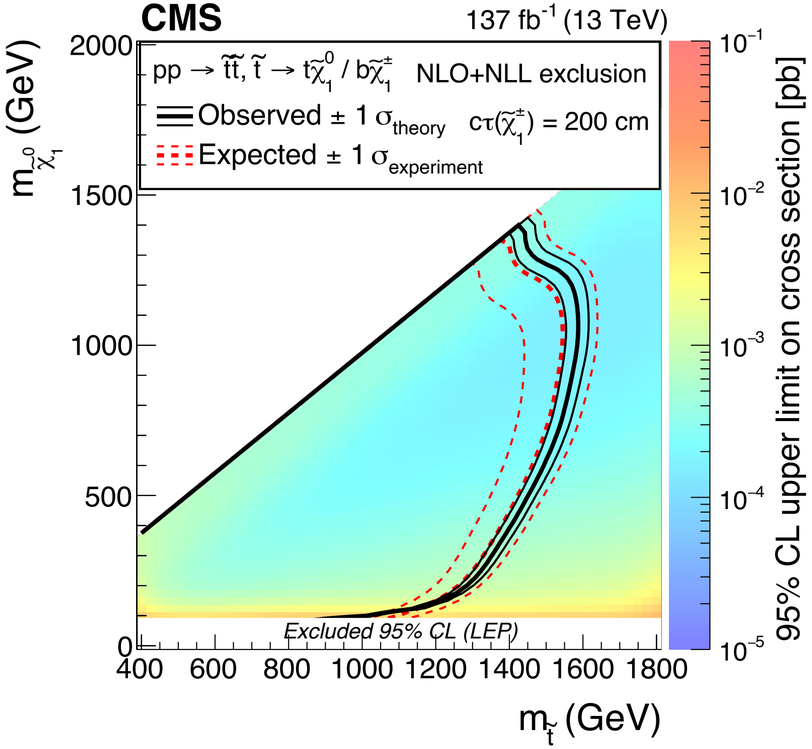


SUSY with disappearing tracks: interpretations

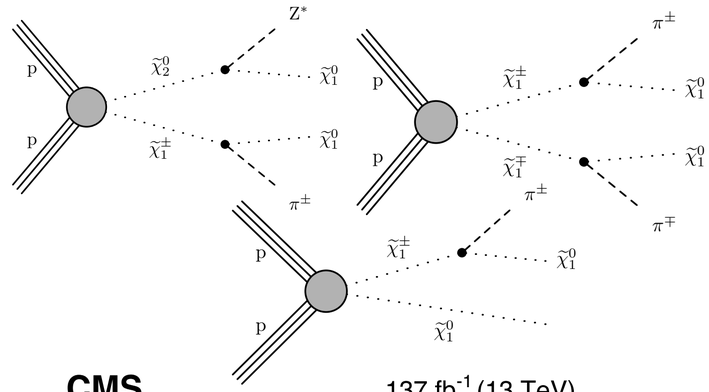
Simplified model of top squarks decaying via long-lived charginos

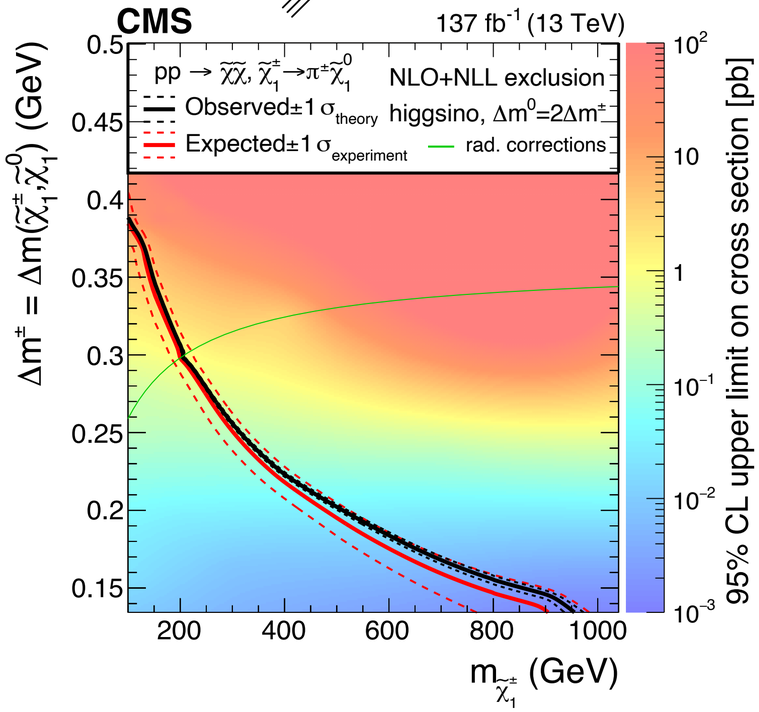






Higgsino DM model assuming nearly degenerate χ_2^0, $\chi_1^\pm$, χ_1^0





Summary

Rich program of experimental searches for SUSY at CMS with LHC Run 2 data. In recent times:

- Extending reach to more challenging scenarios, e.g. compressed spectra, low cross sections, long-lived particles, low/no p_T^{miss}
- Combination of searches helps expand sensitivity by exploiting search complementarity
- Deploying new techniques and strategies, e.g. hadronic probes for electroweakinos, increasing use of ML

The hunt continues!