Searches For Compressed SUSY Scenarios With The CMS Experiment
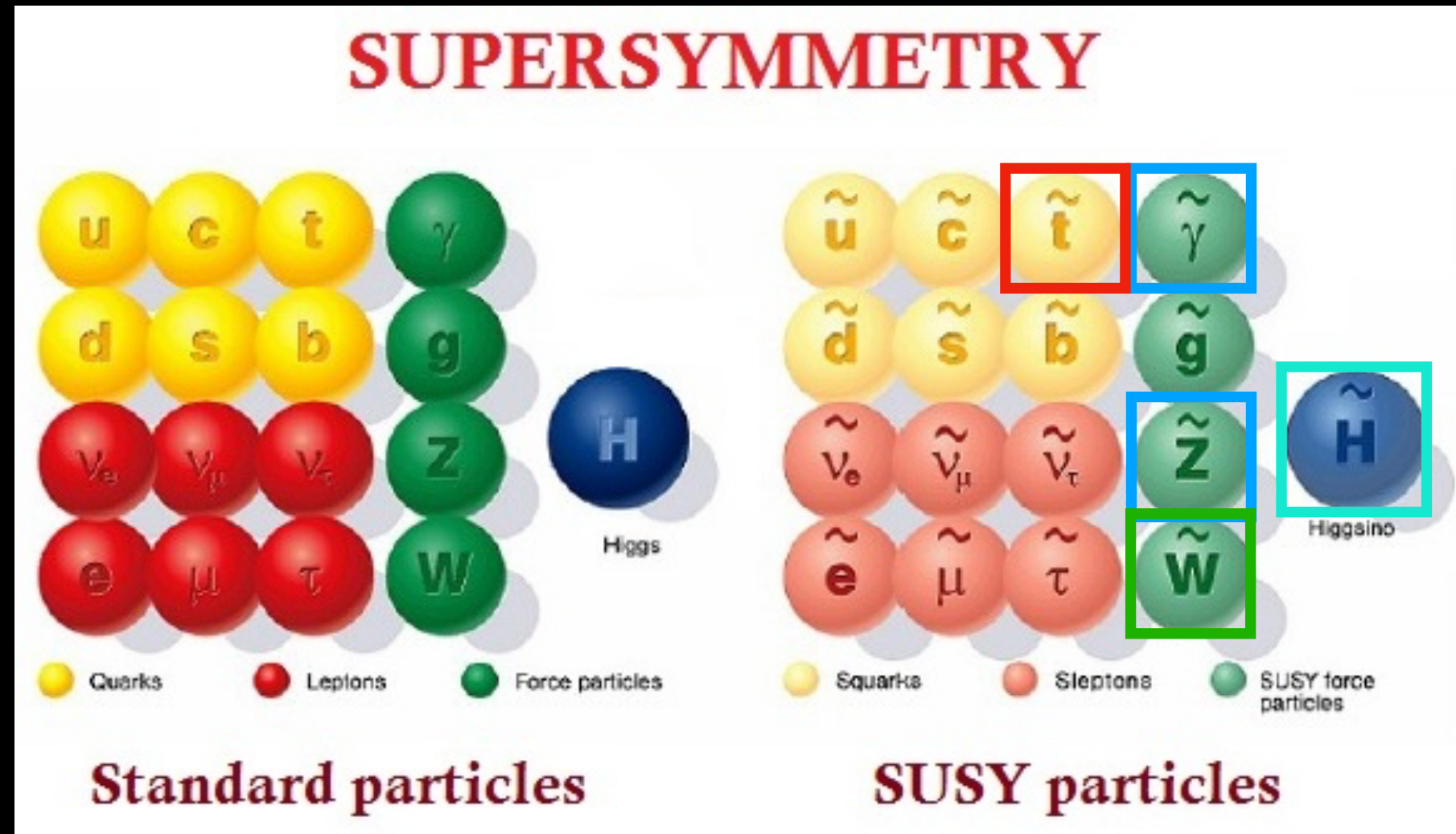
Zach Flowers on behalf of the CMS experiment

Zach Flowers, University of Kansas, ICHEP 2022, July 7th, 2022

Supersymmetry

- Higgs discovery 10 years ago completed the Standard Model

- Each SM particle has a super partner connected by a spin symmetry

- Experimentally accessible with CMS

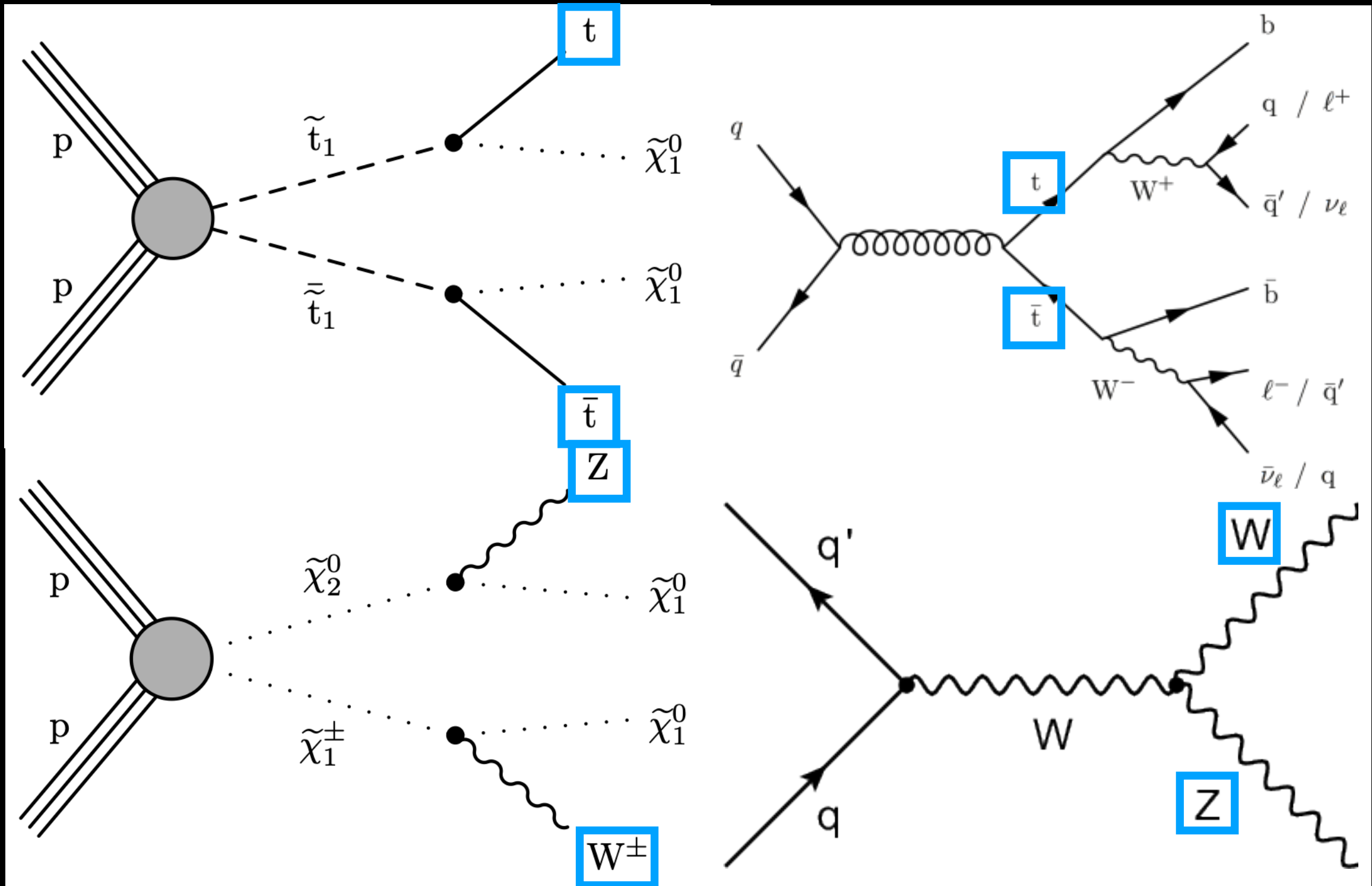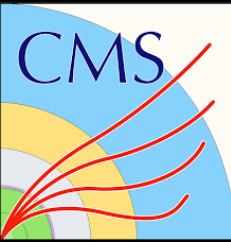- Resolves SM issues
  - Hierarchy problem
  - Dark matter candidate

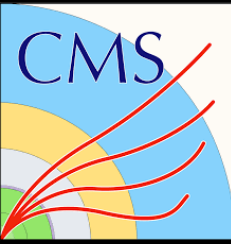- Focus on stops and electroweakinos
  - Decays with tops, W's, and Z's

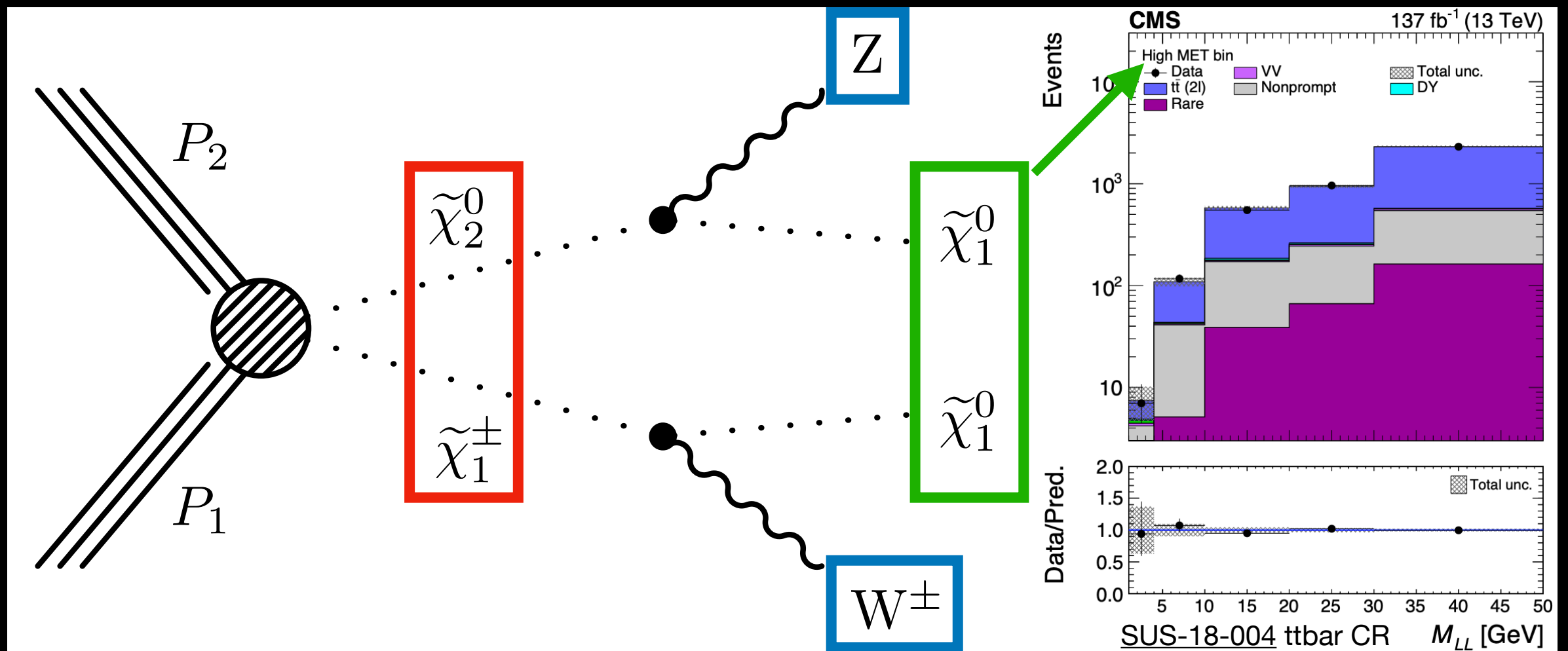$$\tilde{t} \quad \tilde{\chi}_2^0 \quad \tilde{\chi}_1^\pm$$
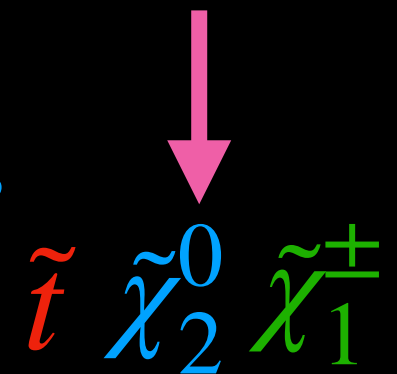
Common Backgrounds Can Mimic SUSY Signatures!
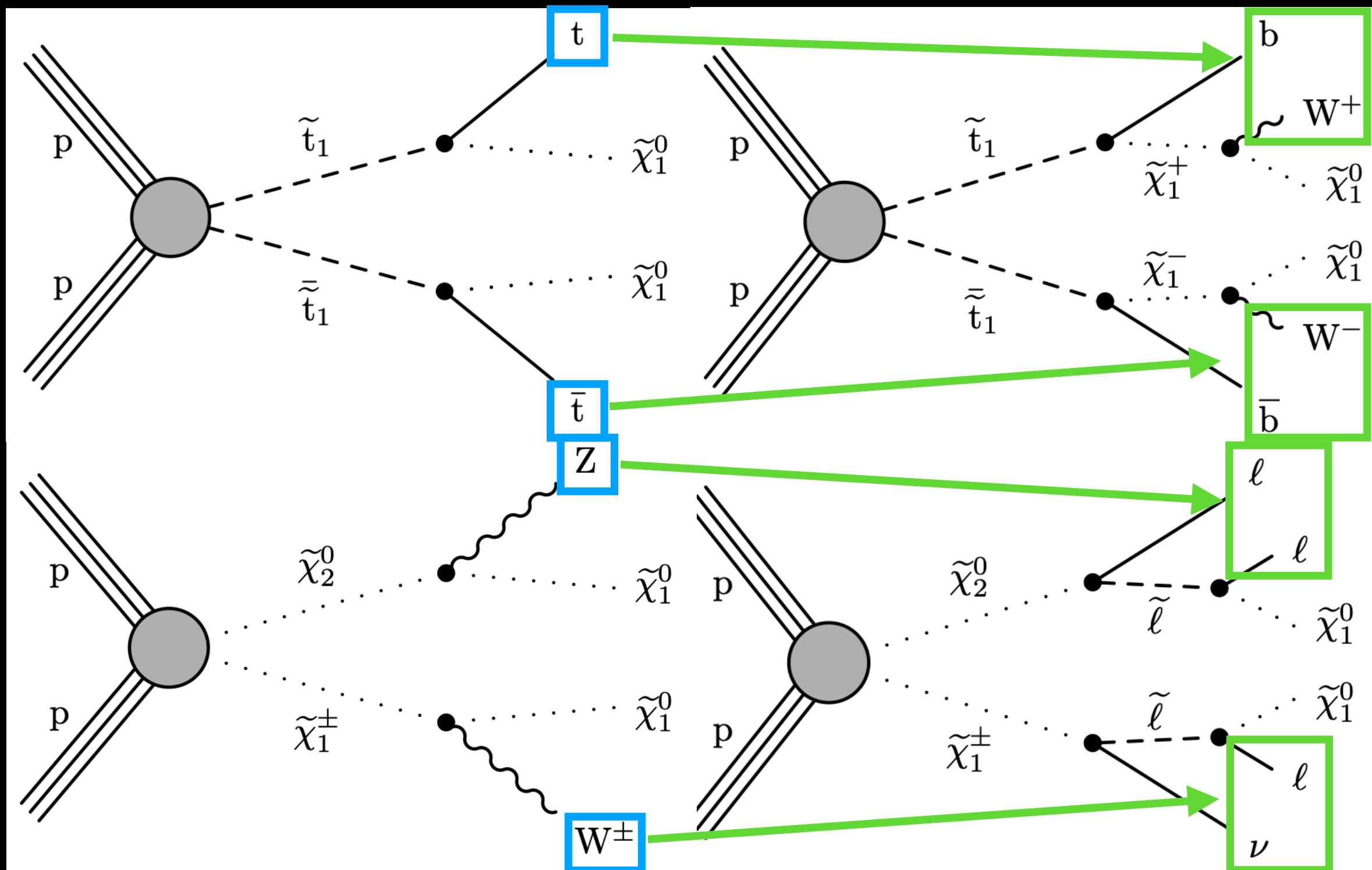
Compressed SUSY

- "Compression" is when the mass splitting between the lightest SUSY particle (LSP) and its parent is small: $m_{\mathrm{SM}} > m_{\mathrm{Parent}} - m_{\mathrm{LSP}}$

  - Makes SM decay products soft and difficult to reconstruct

  - Focus on leptons and $p_{\mathrm{T}}^{\mathrm{miss}}$

Compression Leads To More Complicated SUSY Signatures!

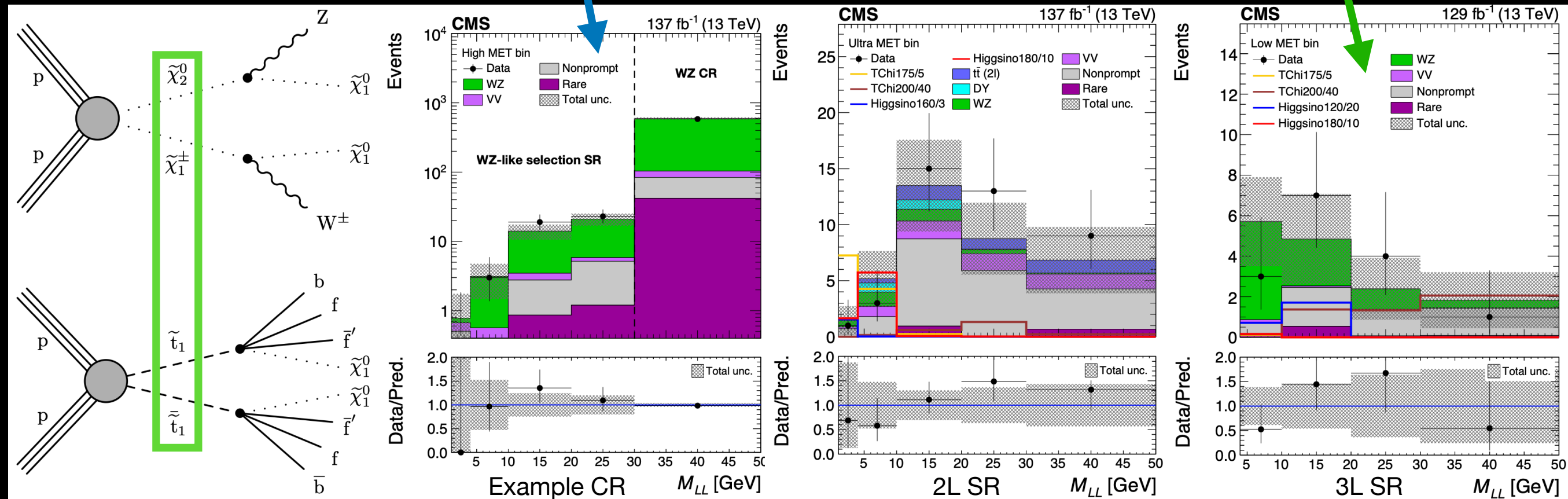Zach Flowers, University of Kansas, ICHEP 2022, July 7th, 2022

SOS Lepton Search

- CMS-SUS-18-004: Searched for electroweakinos and stops in final states with a pair of opposite sign leptons

- Binned in $p_{\mathrm{T}}^{\mathrm{miss}}$

- Used traditional cut and count method

  - Lepton $p_T < 30$ GeV

  - Veto b-tagged jets

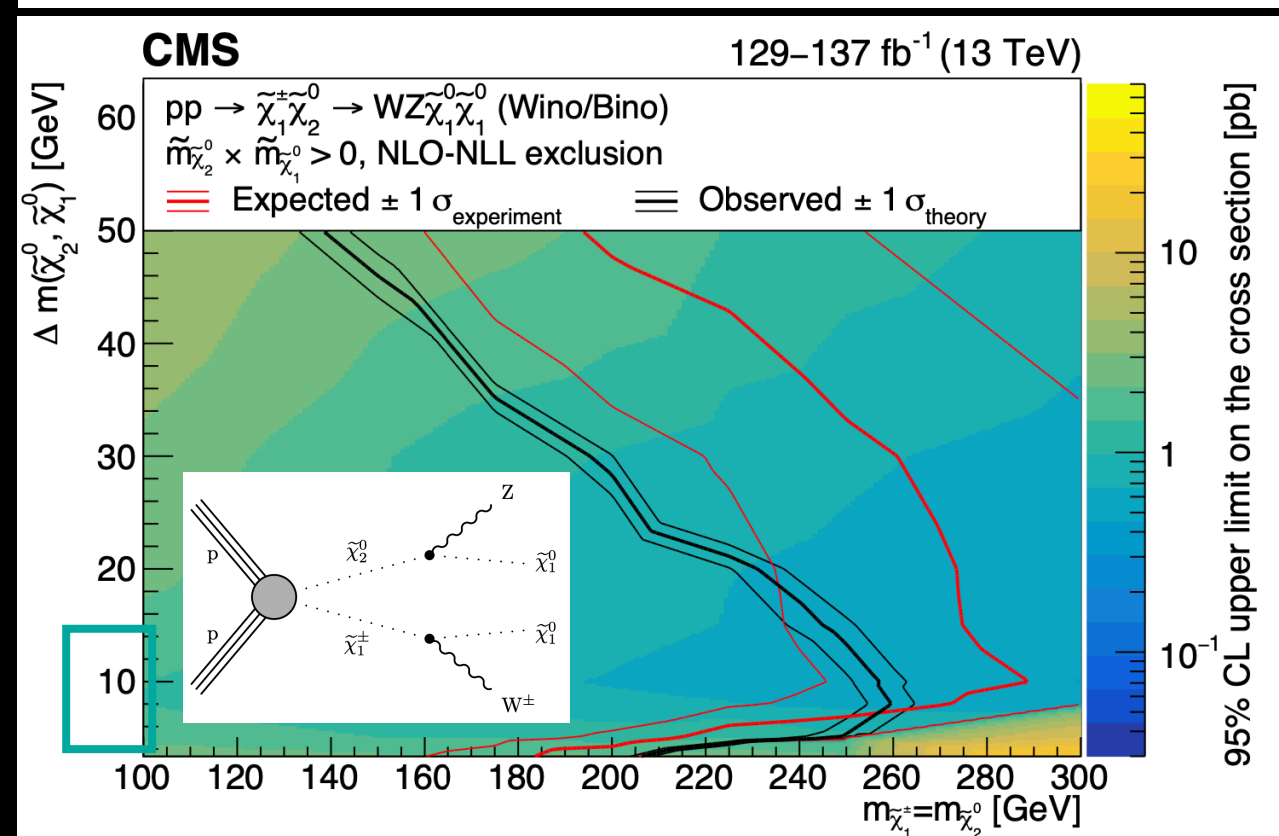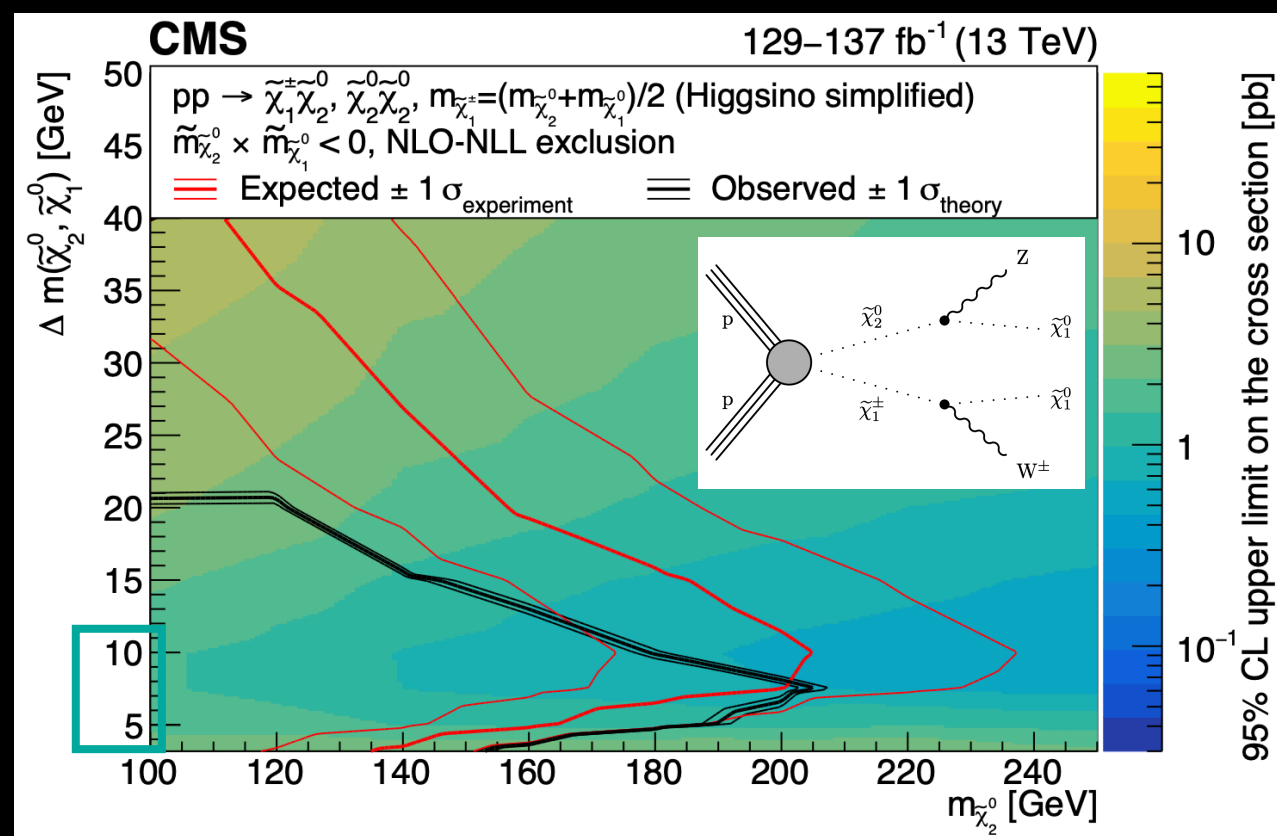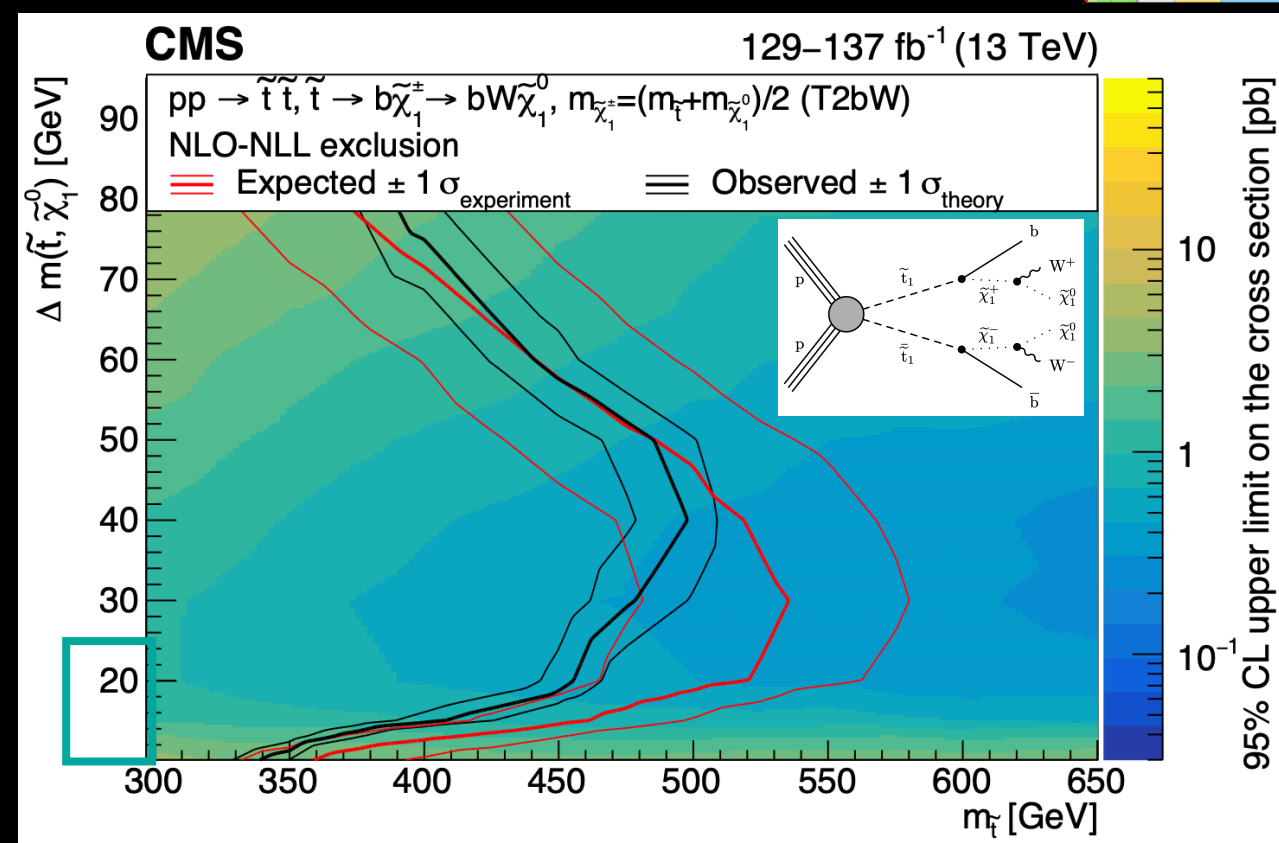 - Able to build upon 2016 analysis by including 3L regions

Soft Final State!

SOS Lepton Results

- Able to probe mass splittings below 10 GeV

- Interpret limits for many different signal models

  - More limits found in JHEP 2204 (2022) 091

Single Lepton MVA Stop Search

- CMS-PAS-SUS-21-003: Used a Boosted Decision Tree (BDT) to discriminate signal from background

- Targeted compressed stops with $\Delta m < 80$ GeV

- Trained individual BDTs for each Δm with 12 kinematic inputs

  - $p_T^{\text{miss}}, p_T^{\text{lep}}, \Delta R(\text{lep}, \text{jet}_b)$

- Implement multiple types of background estimation methods

  - Data-driven method for Wjet and TTbar backgrounds

  - "Tight-to-loose" method for non-prompt background

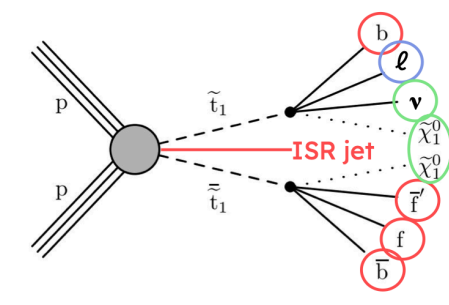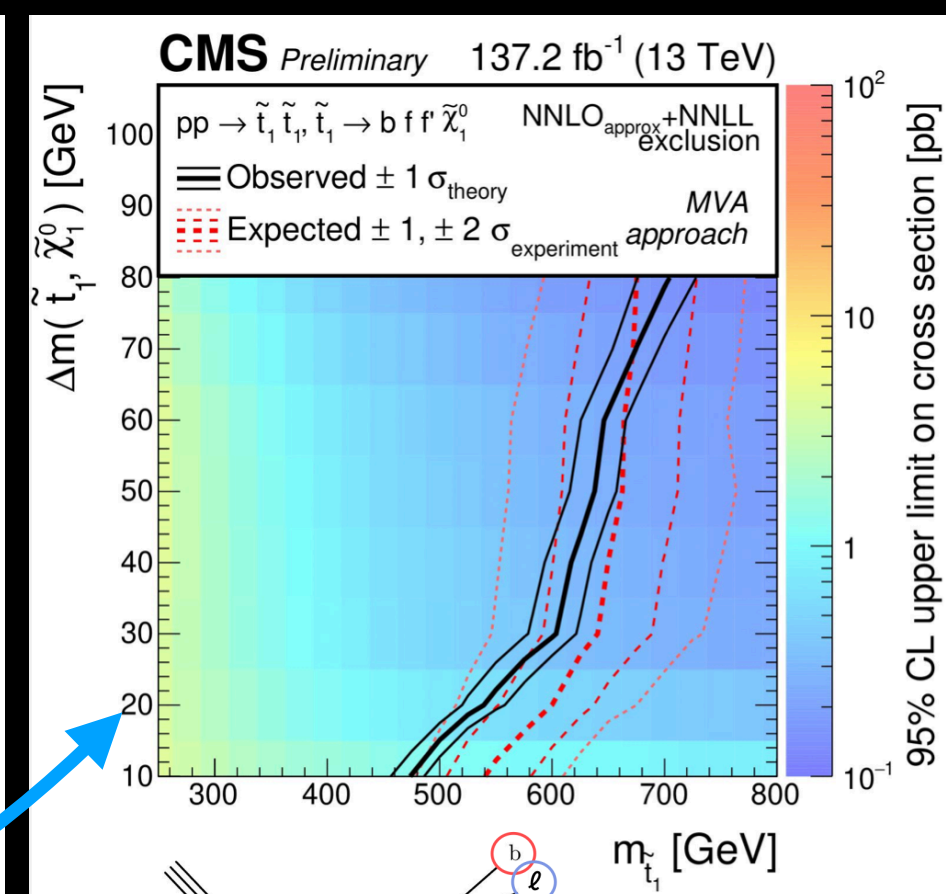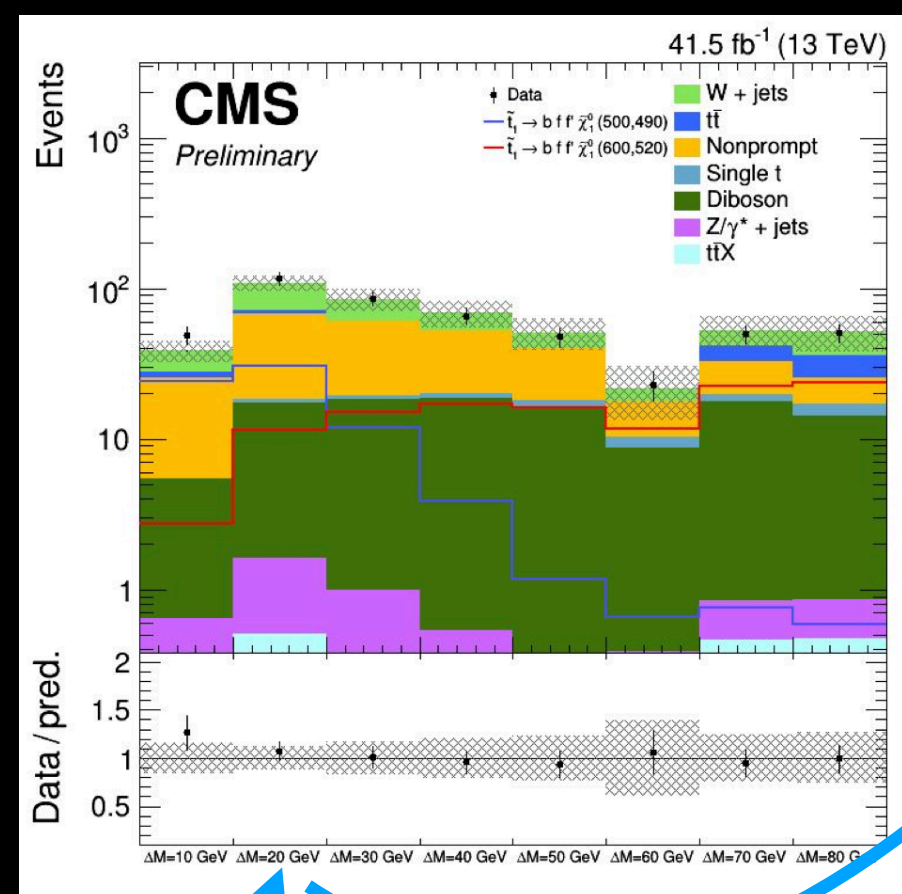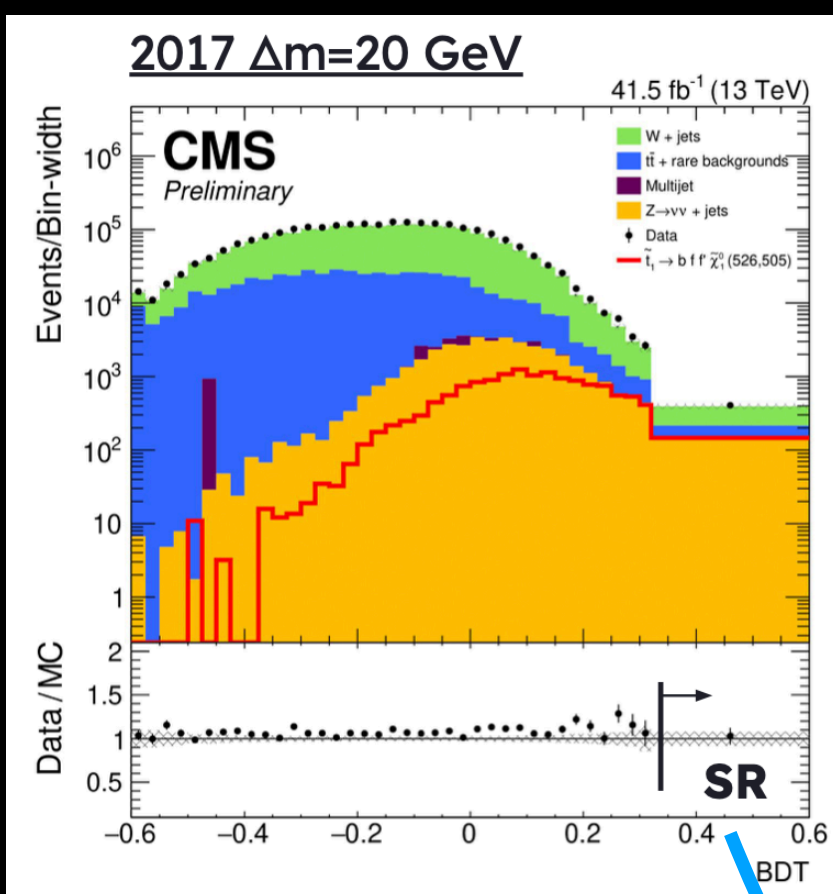Zach Flowers, University of Kansas, ICHEP 2022, July 7th, 2022
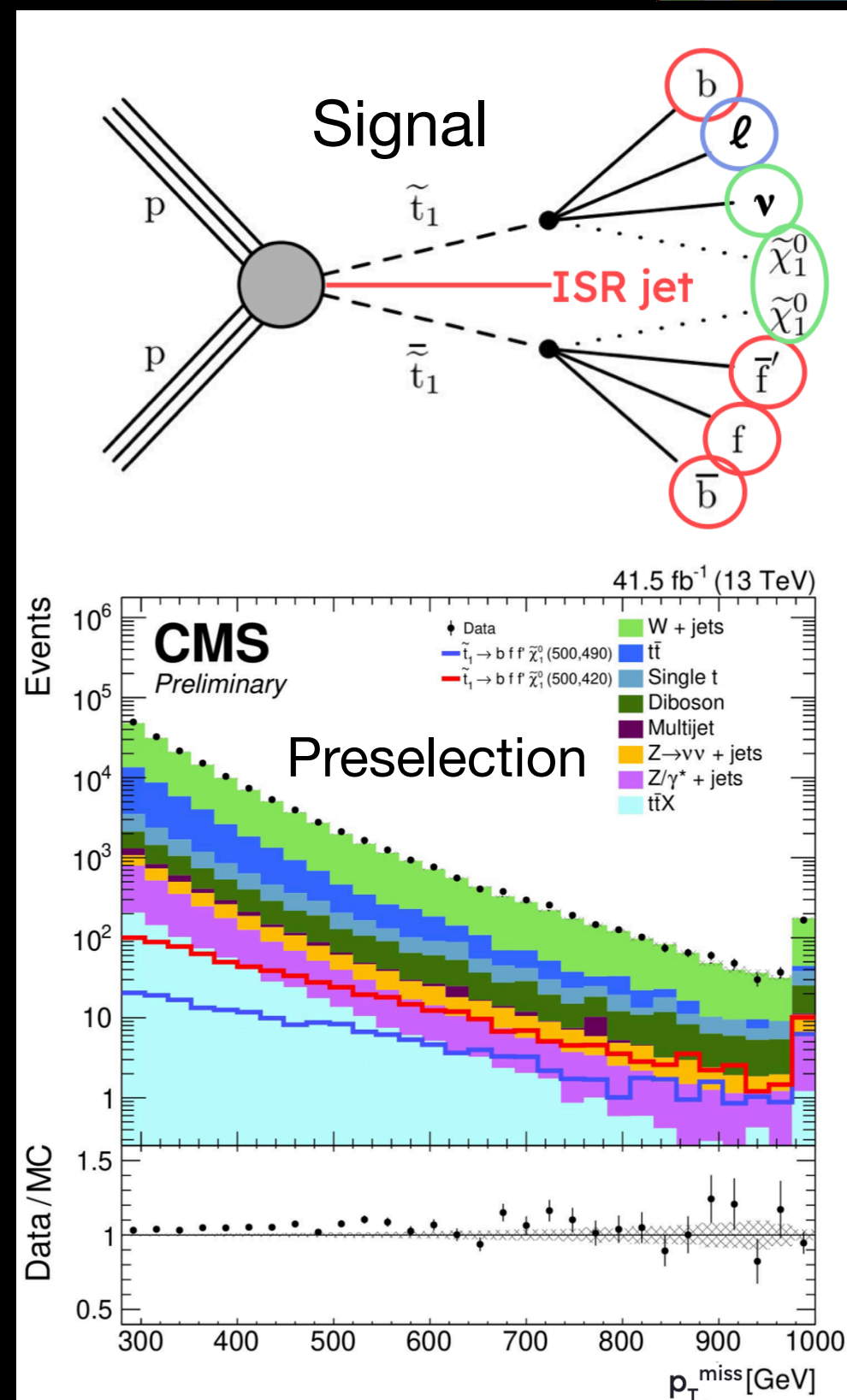
Single Lepton MVA Stop Results

- BDT cut chosen to minimize cross-section upper limit

- BDT outputs used to define Signal Regions

- Excluded stop masses of:
  - 480 GeV at $\Delta m = 10$ GeV
  - 700 GeV at $\Delta m = 80$ GeV


Example BDT discriminant for one mass point in 2017

See Pablo's Talk For More Details

Chargino & Neutralino Search

- <u>CMS-SUS-19-012</u>: Searched for electroweakinos in multi-lepton final states with a parametric neural network (NN)

  - Explicitly required an OSSF lepton pair

- NN trained in Δm using variables like M_{ll}^{OSSF}, and p_T^{miss}
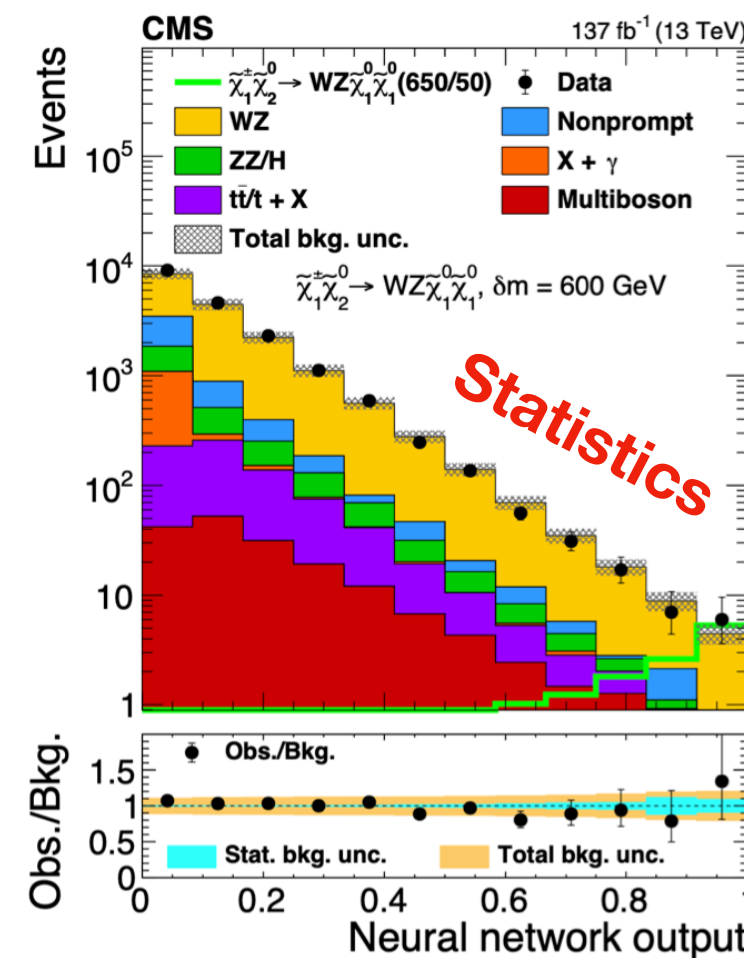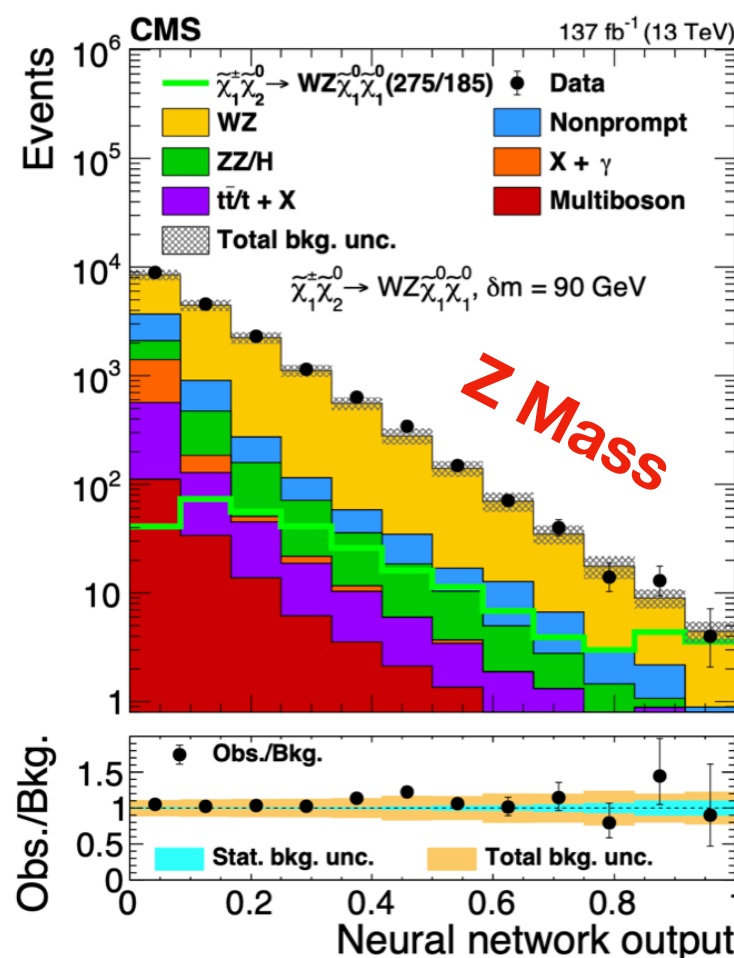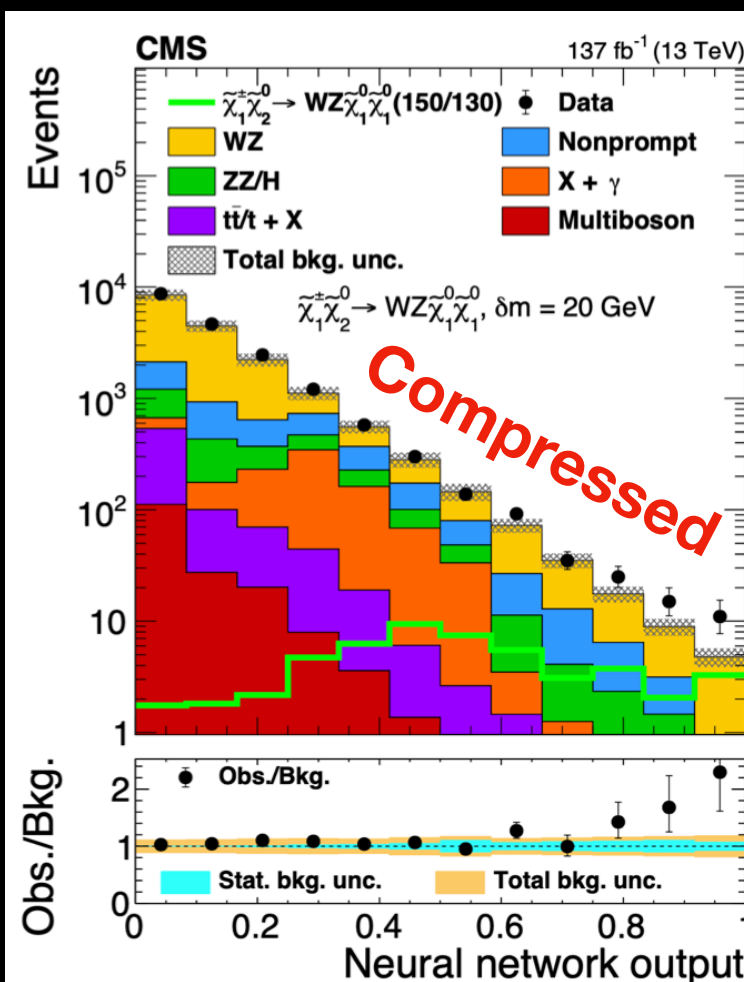
  - Excellent performance at low Δm

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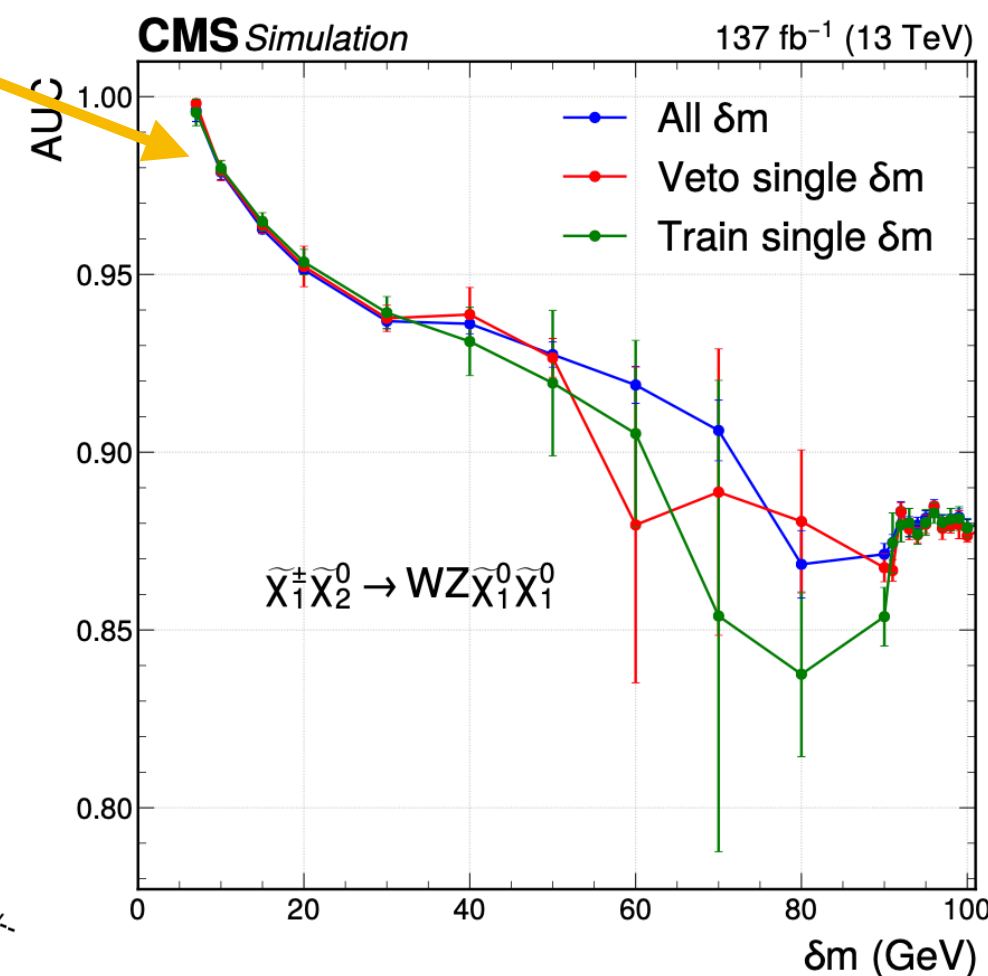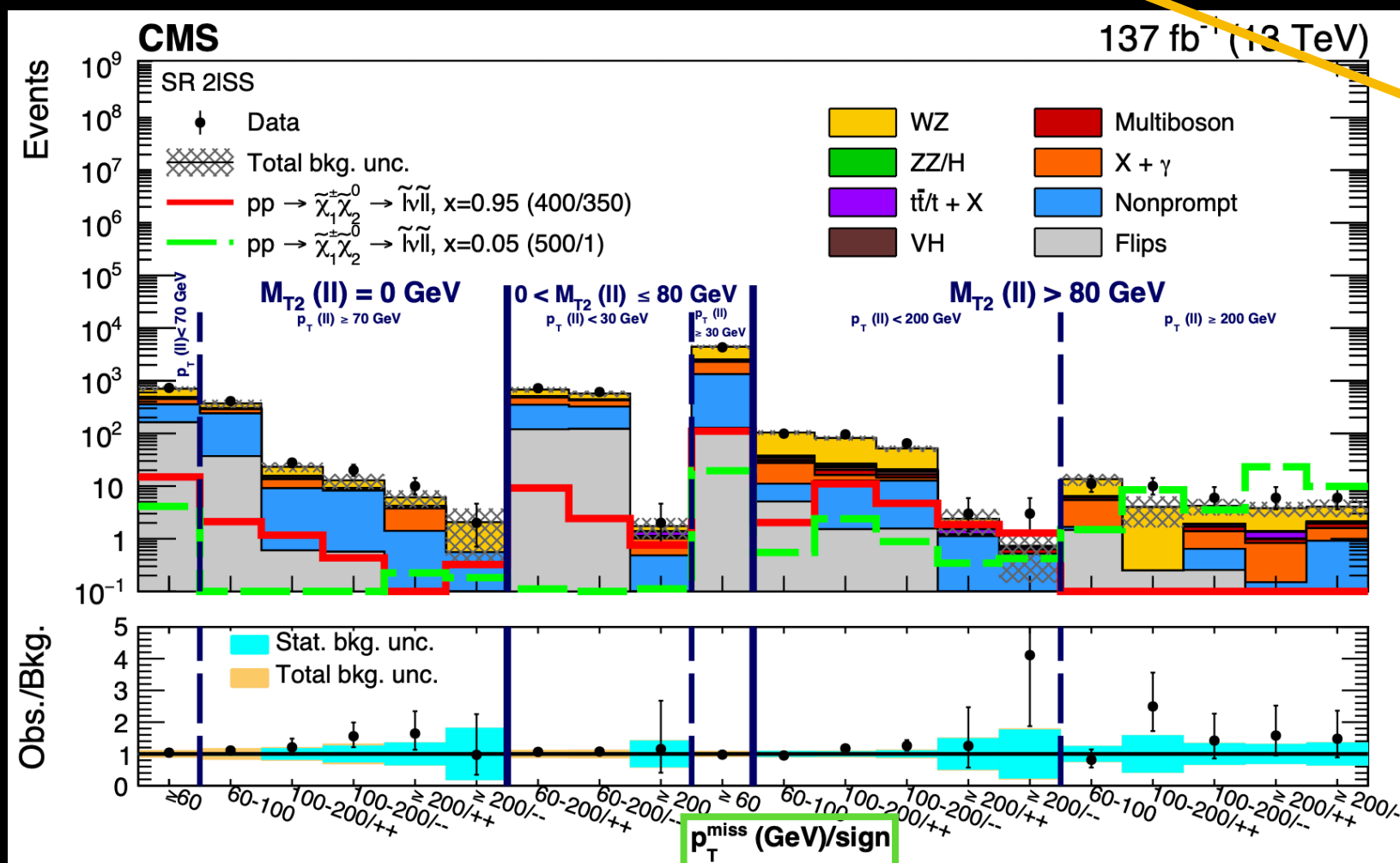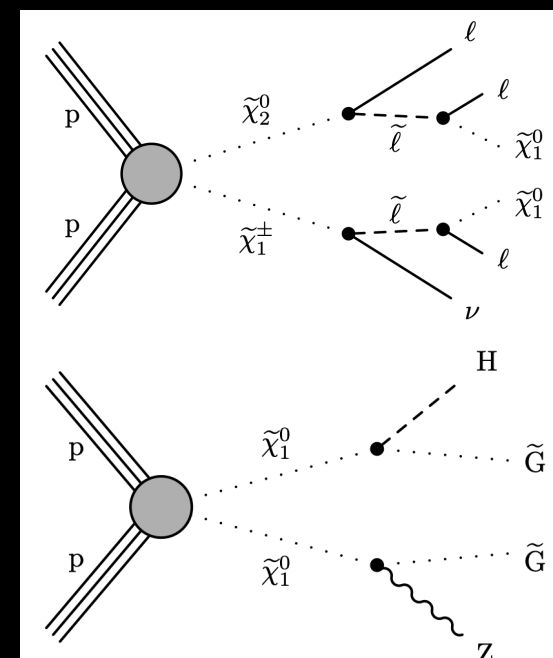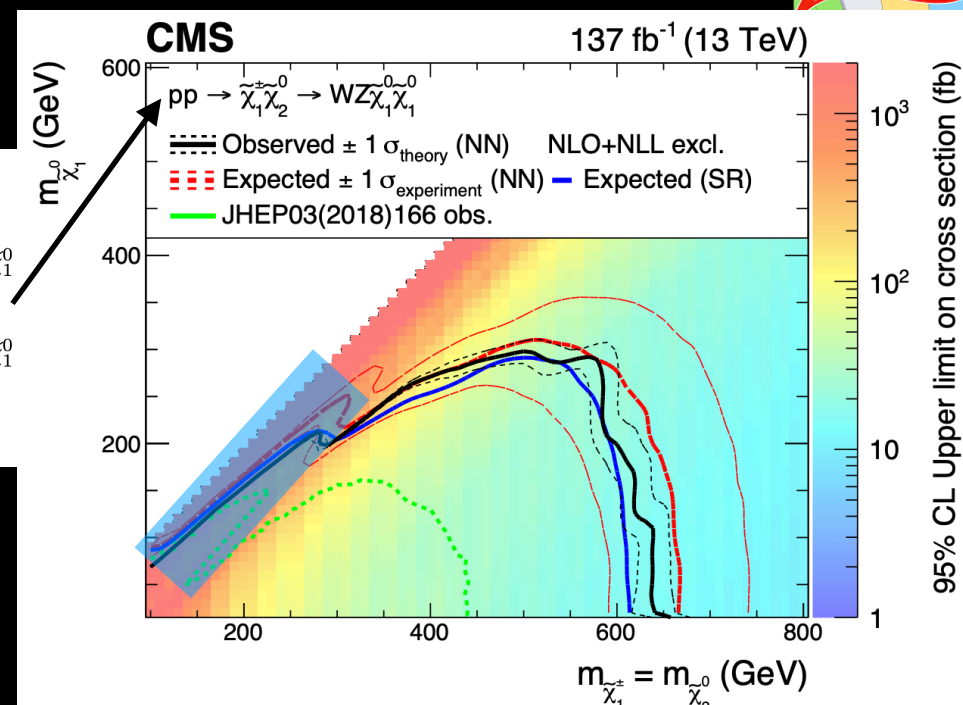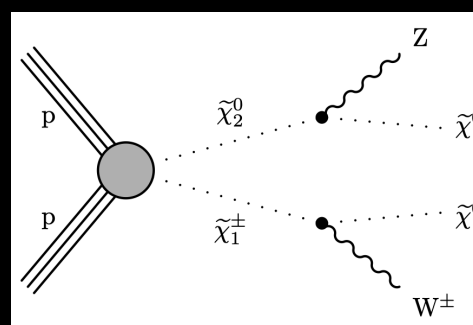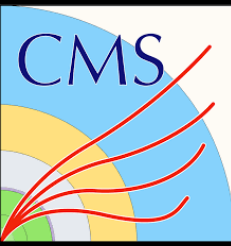
- Mass splitting influences shape of the signal BDT discriminant

- Each δm has different challenges to overcome

- Limits pushed into compressed phase space

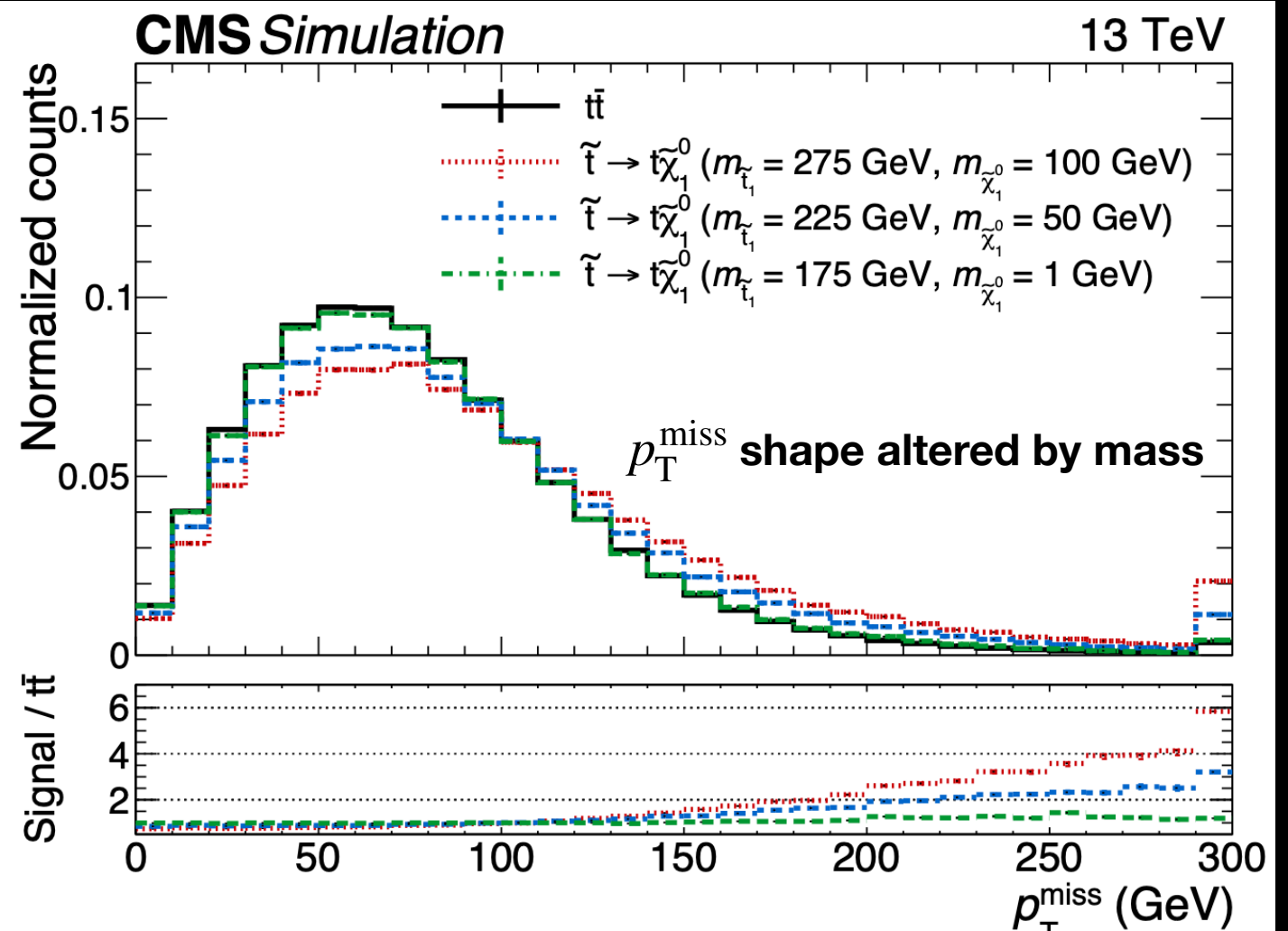 - Additional limits found in JHEP 04 (2022) 147
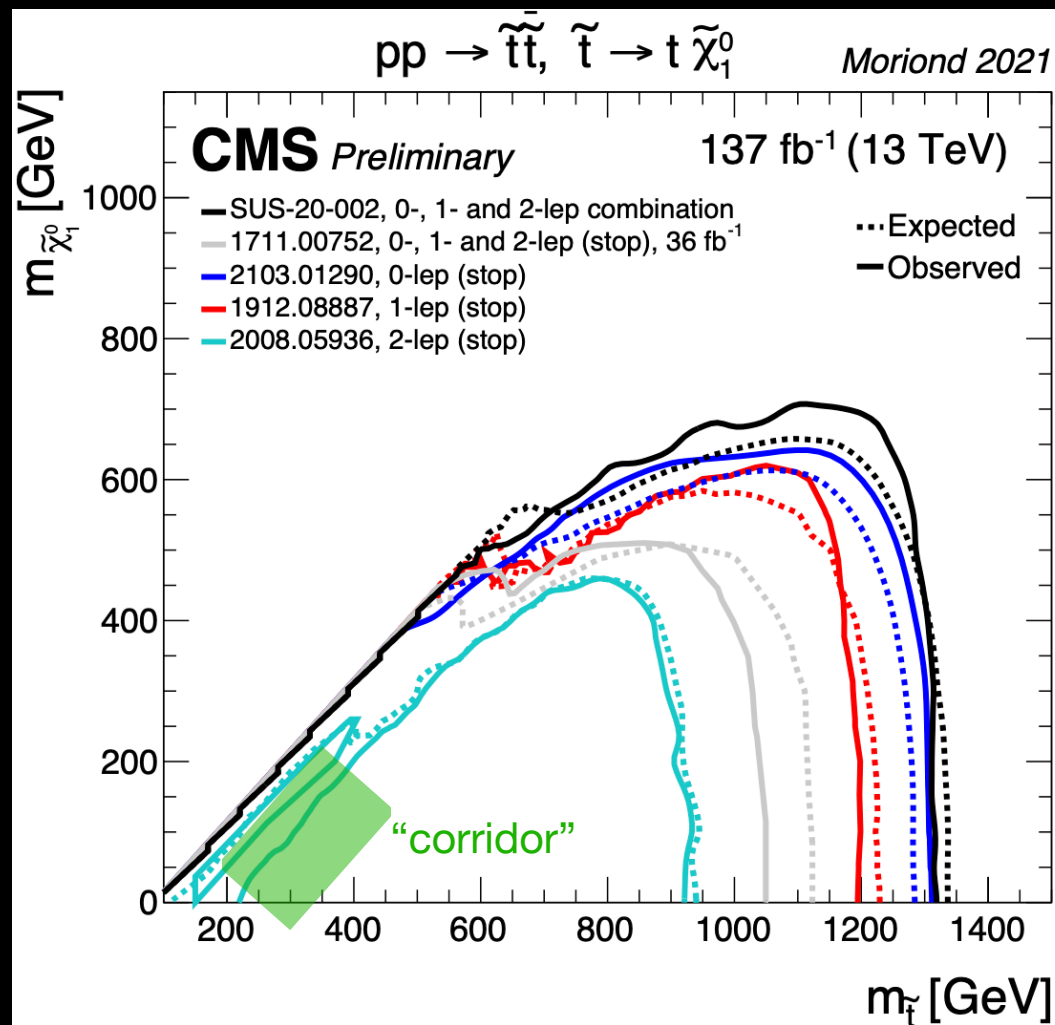
Top Corridor Search

- <u>CMS-SUS-20-002</u>: Searched for top squarks along the "top corridor"

  - $\Delta m \approx m_{\text{top}}$

- Relies on precisely estimating ttbar background

- Use NN that includes the stop and LSP masses, and other kinematic quantities:

  - $m_{\text{T2}}(ll), p_{\text{T}}^{\text{miss}}, H_T$

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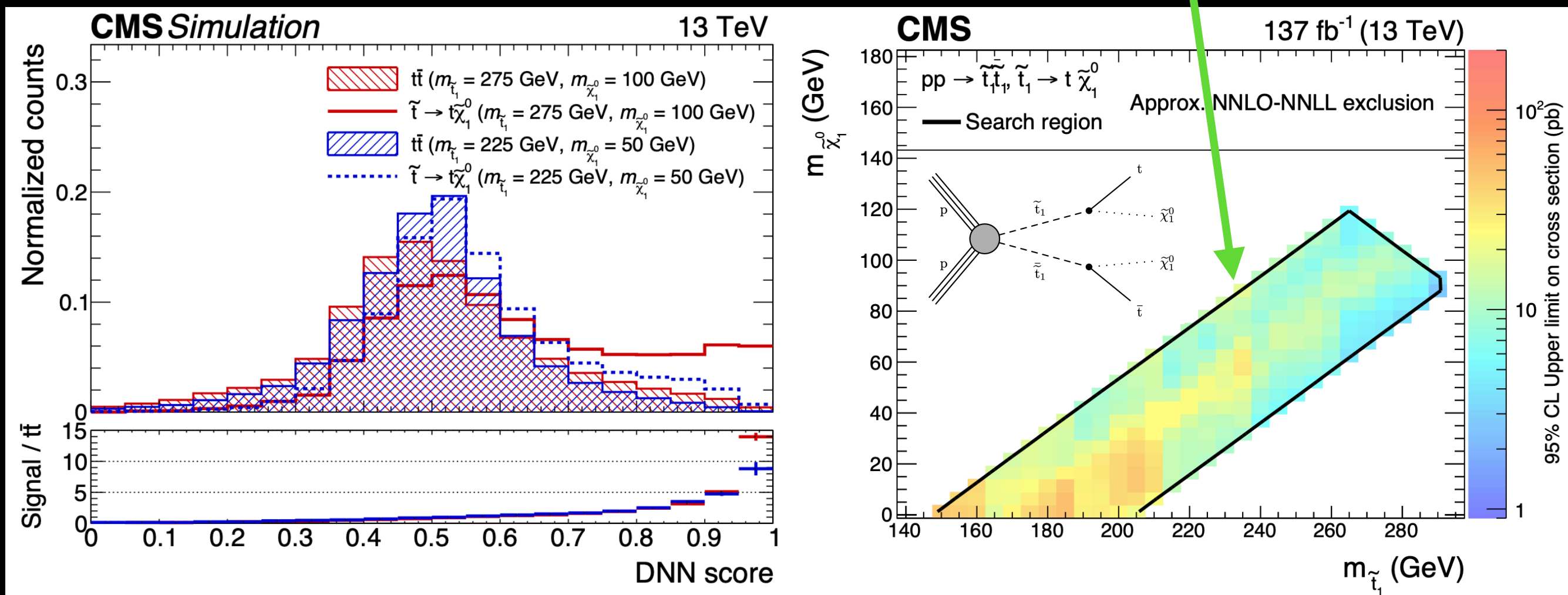
Top Corridor Results

- Each mass point has a different DNN score distributions for signal and background

- DNN output used to extract signal

- Corridor region fully ruled out!
  - Eur.Phys.J.C 81 (2021) 11, 970

Summary

- Compressed SUSY is a region of phase space that was not deeply covered by earlier searches

- Overview of results from newer searches for compressed SUSY have been presented

- CMS still has more to come with Run II in terms of both analyses and summary papers

- With Run III starting this week on the 10 year anniversary of the Higgs discovery there has never been a better time to search for new physics!

Backup