



# Search for 3<sup>rd</sup> Generation Squark Production with CMS

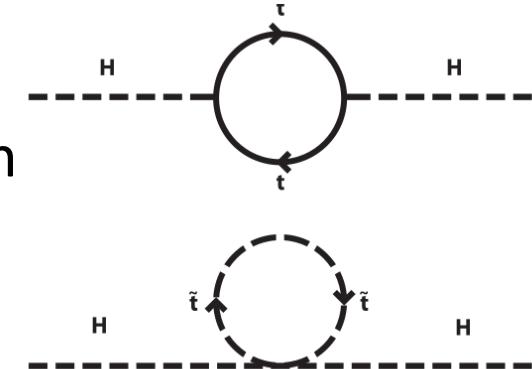
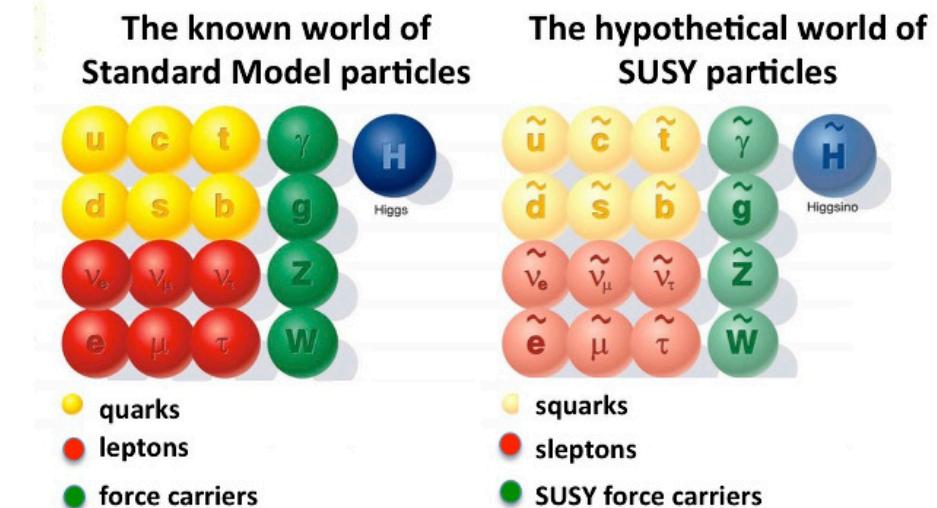
Zhenbin Wu

*(University of Illinois at Chicago)*

*-- On behalf of the CMS Collaboration*

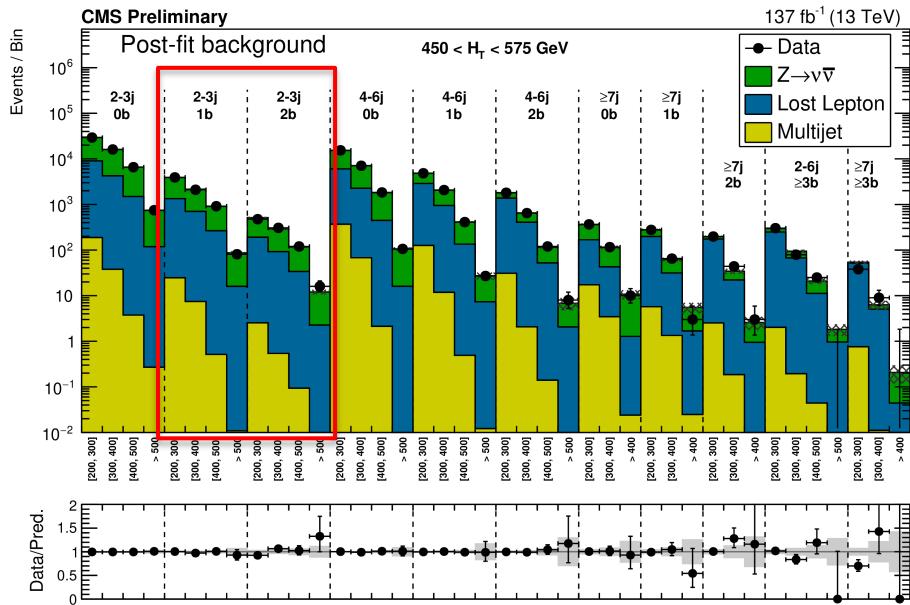
# Introduction

- Supersymmetry is one of the most promising extensions of the SM
- With R-parity conservation, the lightest supersymmetric particle (LSP) is a dark matter candidate
- SUSY provides the cancellation of the Higgs boson quadratic mass renormalization between top and top squark (stop)
- Naturalness arguments prefer **light** stop/sbottom, reachable by LHC
- Use **Simplified Model Spectra** as guideline, consider  $\tilde{\chi}_1^0$  as LSP

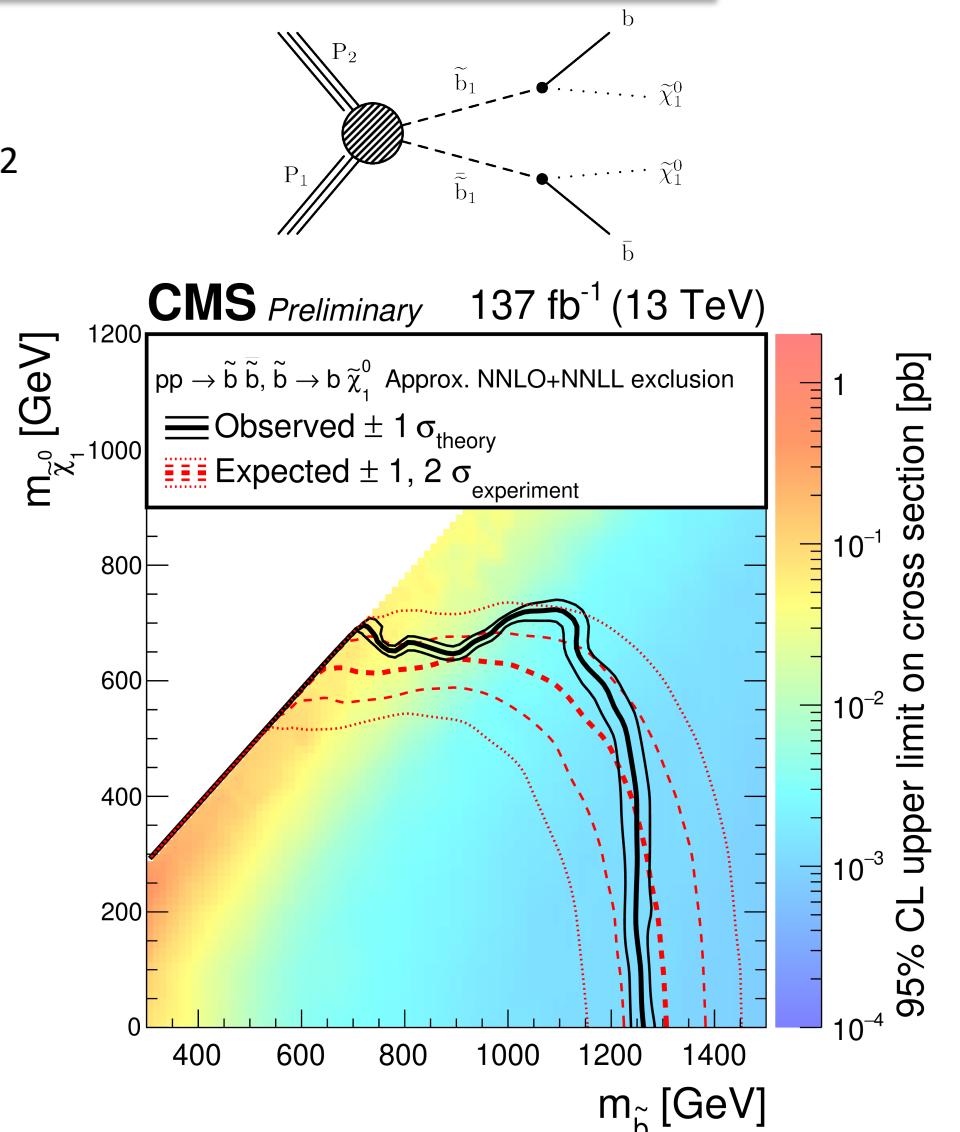


# Bottom Squark

- Inclusive searches in all hadronic final state, binned in  $H_T$ ,  $N_j$ ,  $N_b$ ,  $M_{T2}$
- Extend reach by  $\sim 100\text{GeV}$  on sbottom mass compared to  $36\text{fb}^{-1}$  result

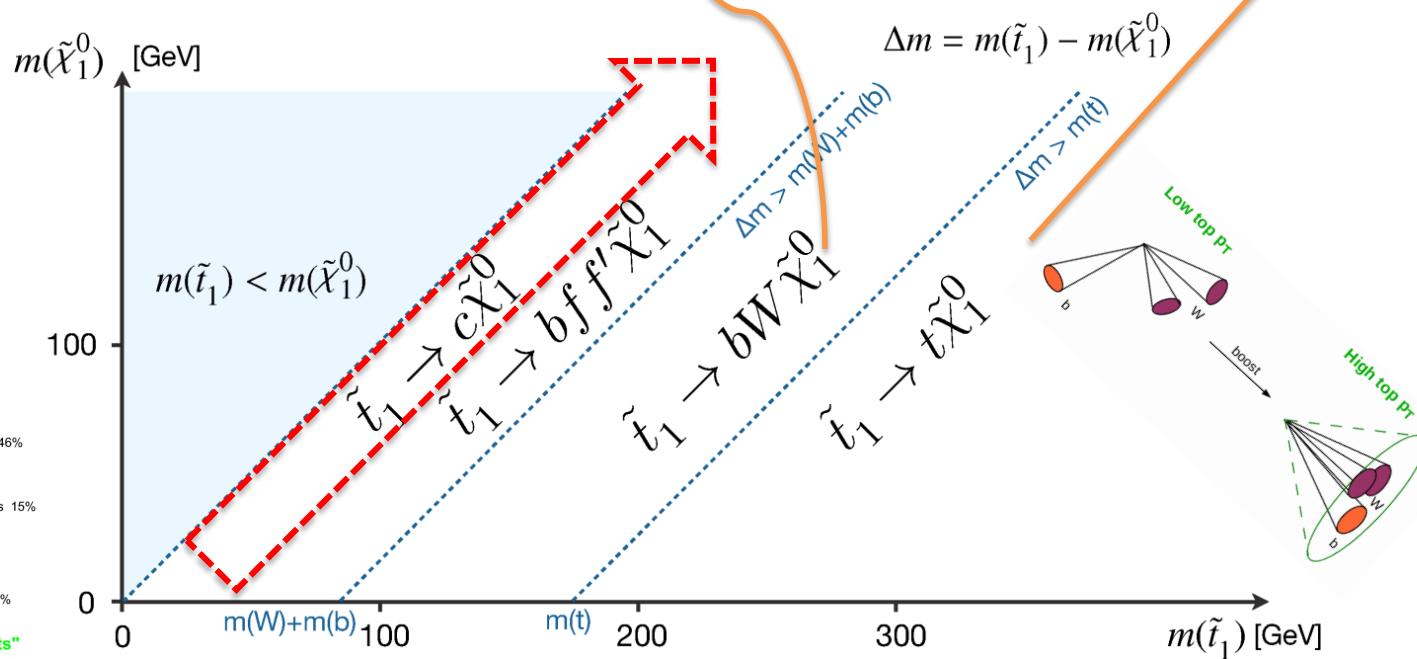
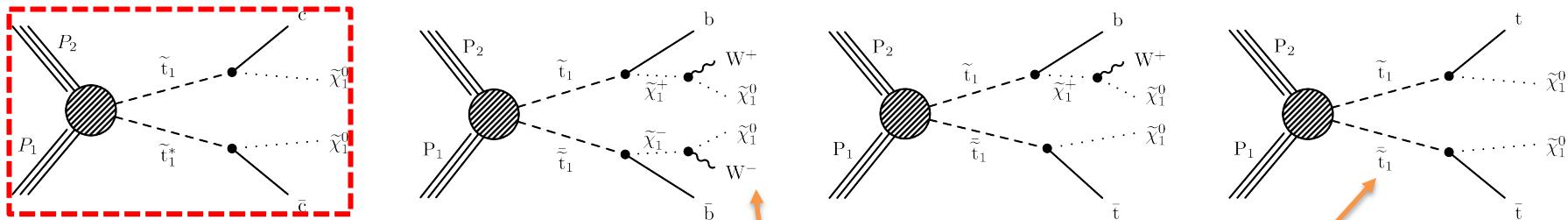


[CMS-PAS-SUS-19-005](#)



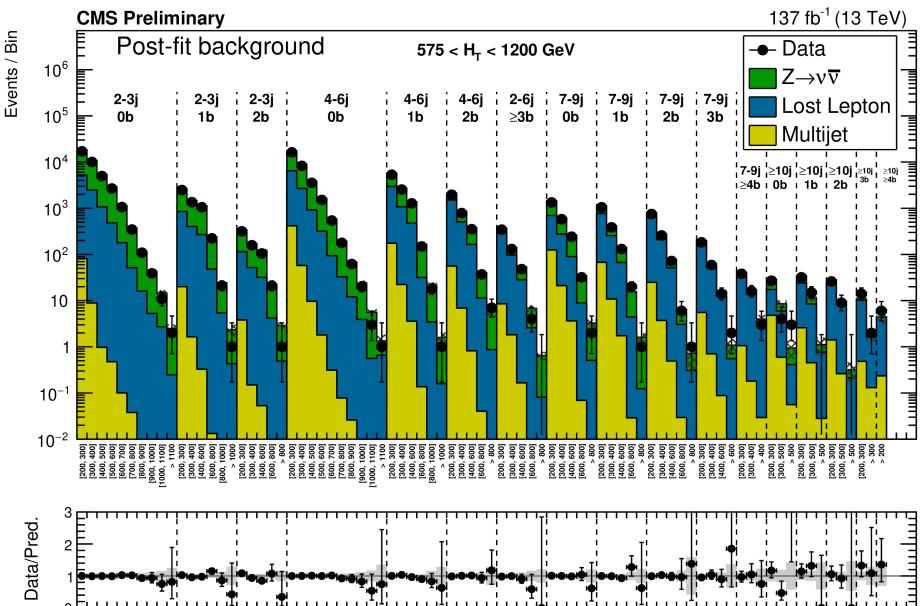
# Top Squark

## Enriched final states for top squark searches

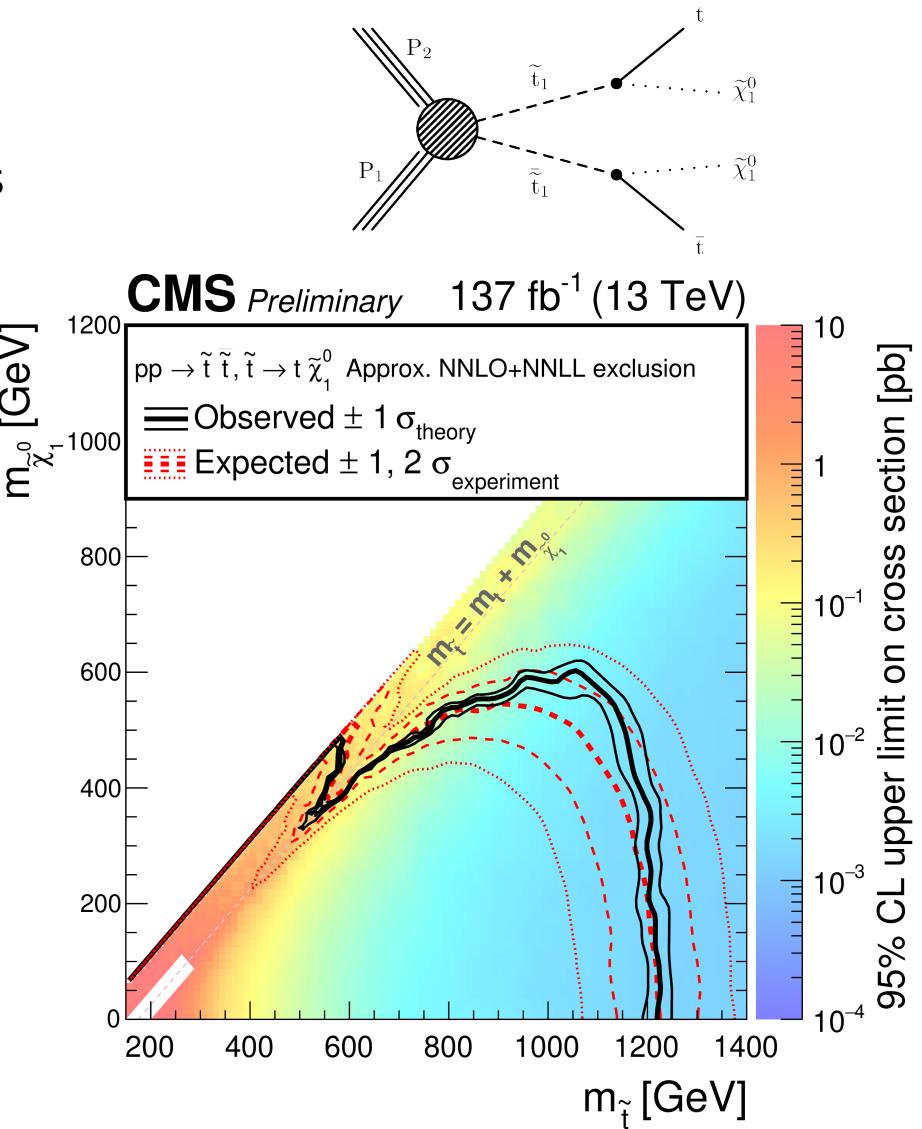


# Top Squark with $M_{T2}$

- Inclusive searches in all hadronic final state, binned in  $H_T$ ,  $N_j$ ,  $N_b$ ,  $M_{T2}$
- Extend reach by  $\sim 130\text{GeV}$  on stop mass compared to  $36\text{fb}^{-1}$  result
- Blinded top corridor due to finite granularity of the fastsim MC samples



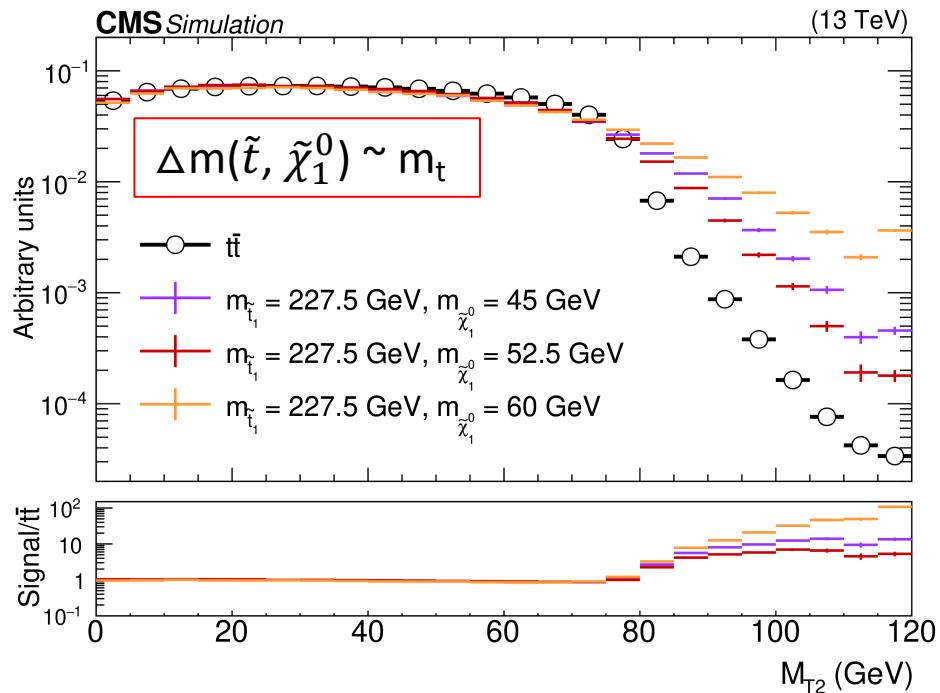
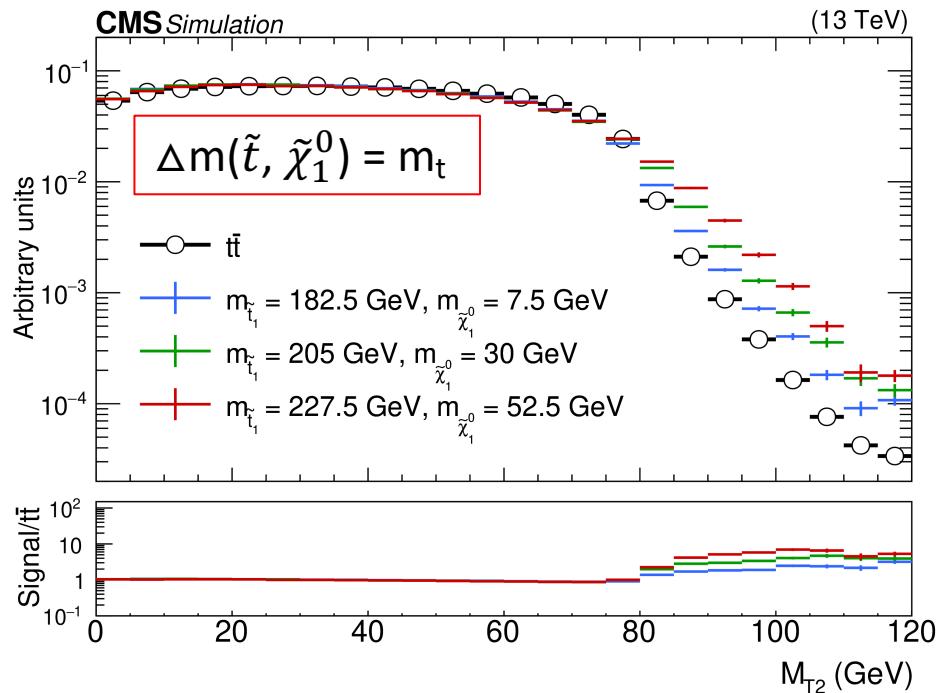
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# Light Stop with 2LOS

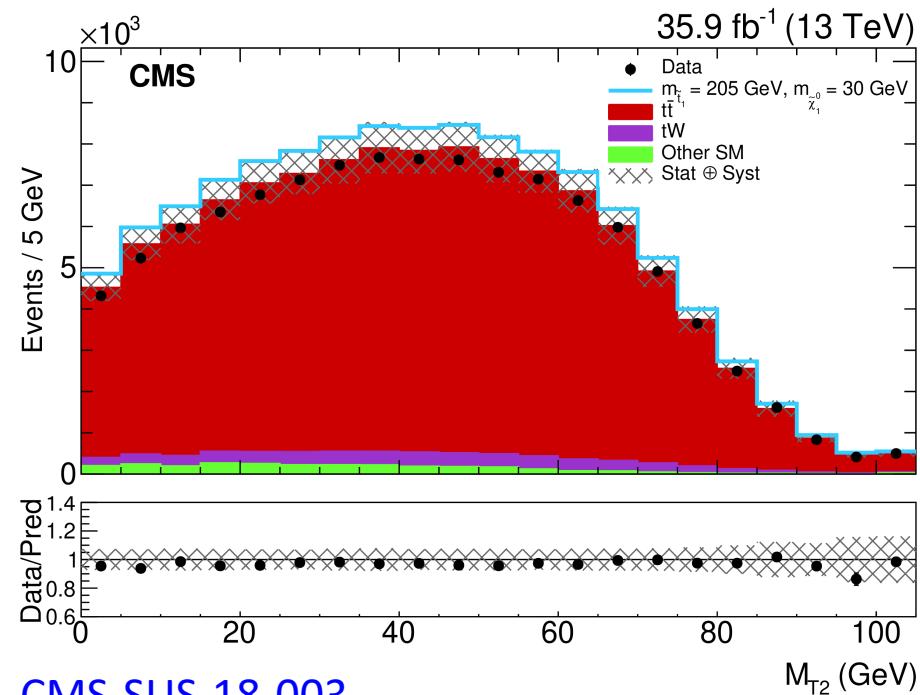
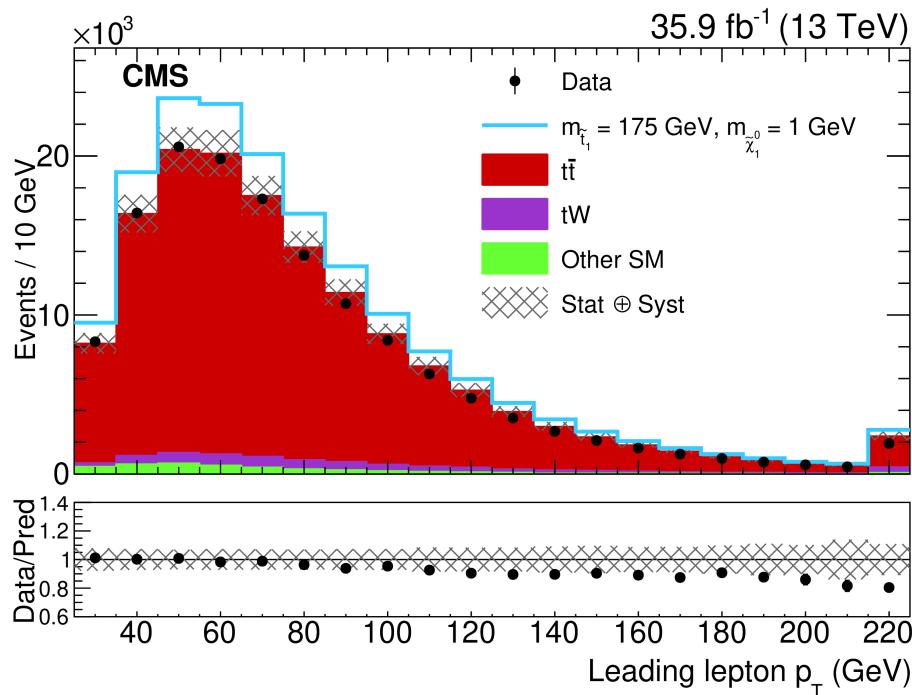
- A dedicated search for light top squarks ( $m_{\text{stop}} - m_{\text{LSP}} \sim m_{\text{top}}$ ) in the  $e^\pm \mu^\mp$  final state
- Very similar kinematics to top-pair production, with  $\sim 15\%-3\%$  cross section of  $t\bar{t}$
- Discrimination through  $M_{T2}(e\mu)$  shape  $M_{T2} = \min_{\vec{p}_{T,1}^{\text{miss}} + \vec{p}_{T,2}^{\text{miss}} = \vec{p}_T^{\text{miss}}} (\max [m_T(\vec{p}_T^{\ell 1}, \vec{p}_{T,1}^{\text{miss}}), m_T(\vec{p}_T^{\ell 2}, \vec{p}_{T,2}^{\text{miss}})])$ ,

[CMS-SUS-18-003](#)



# Light Stop with 2LOS

- Dominated by ttbar background in  $e\mu$  pair +  $\geq 2$  jets +  $\geq 1$  btag
- Sensitivity reached through precise estimate of ttbar background  
[\(JHEP 1608 \(2016\) 029, CMS-PAS-TOP-16-021\)](#)
- No data excess observed over background prediction

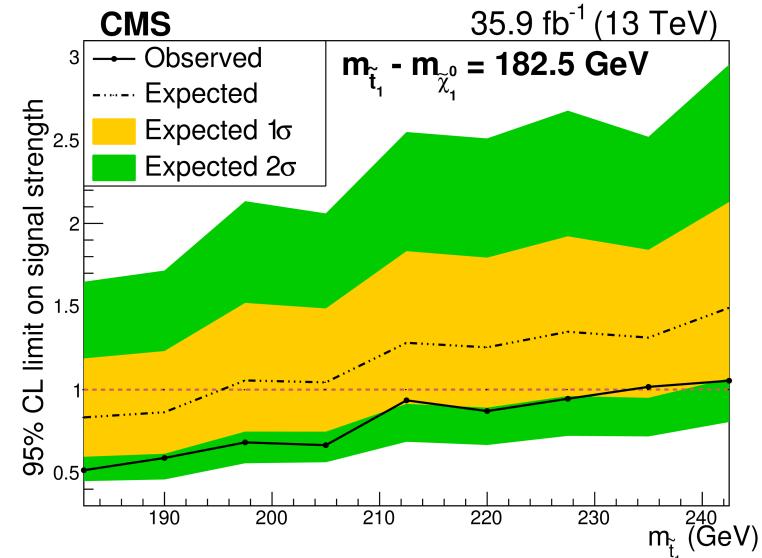
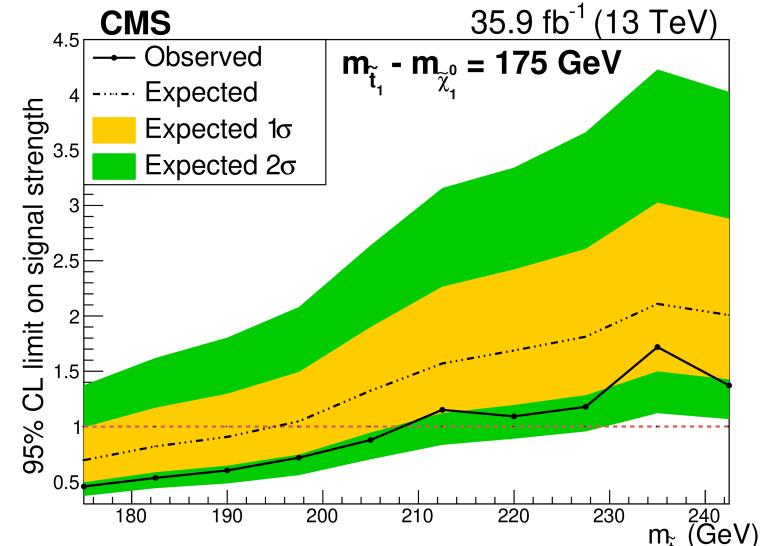
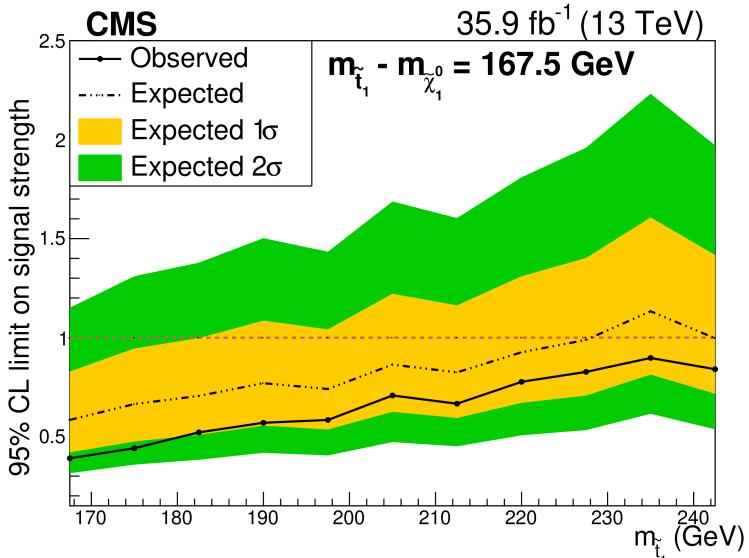


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# Exclusions

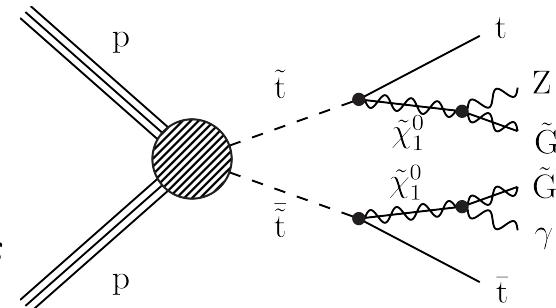
- Observed upper limits are close to the  $\sim 1$  sigma expected band.
- Exclusion limits in the ttbar diagonal for stop masses of up to  $\sim 205$  GeV and up to  $\sim 235$  GeV for  $\Delta m \sim 7.5$  GeV.

[CMS-SUS-18-003](#)



# Stop with GMSB

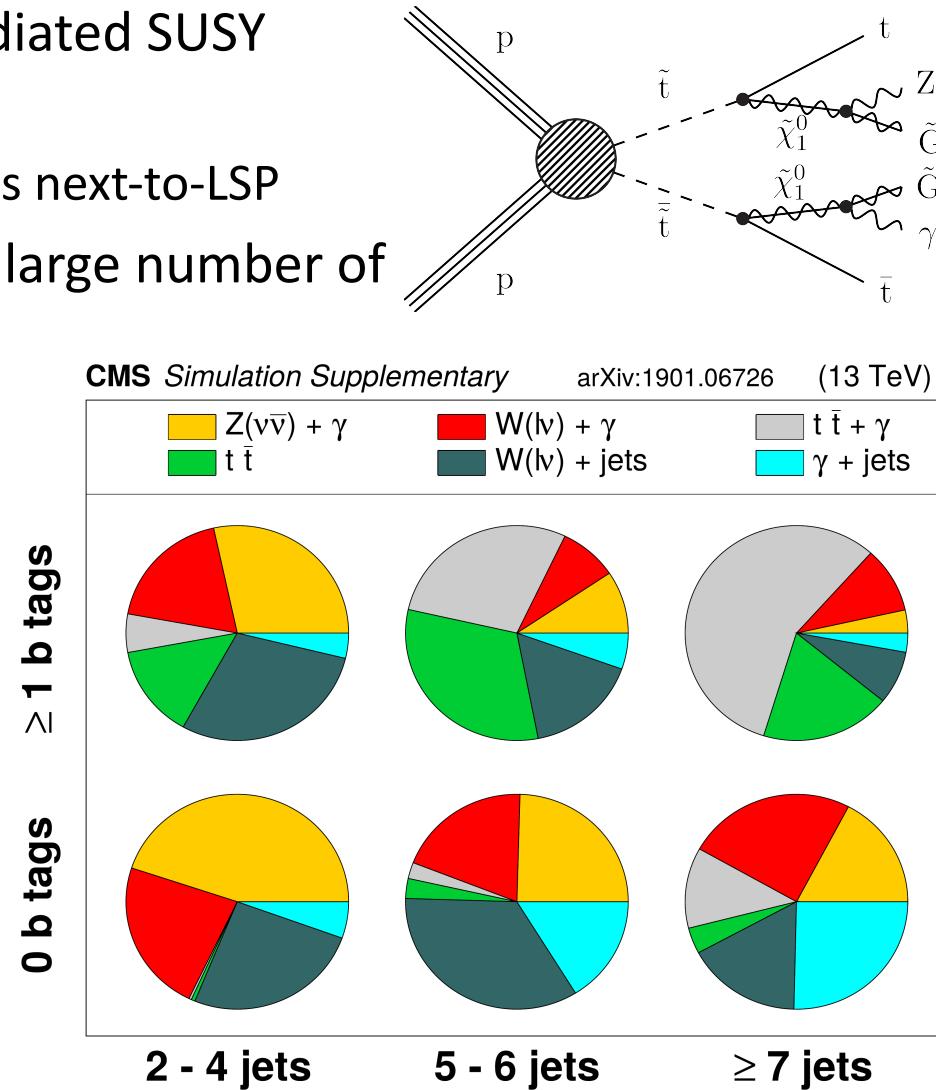
- Simplified models with gauge-mediated SUSY breaking (GMSB)
  - Gravitino ( $\tilde{G}$ ) is the LSP, while  $\tilde{\chi}_1^0$  is next-to-LSP
- Search with  $\geq 1$  photon,  $p_T^{\text{miss}}$ , and large number of jets and b-tagged jets



## Backgrounds:

- Lost lepton and hadronic  $\tau$  from  $t\bar{t} + \gamma$ ,  $W + \gamma$
- Electron fake  $\gamma$ , from  $t\bar{t}$ ,  $W + \text{jets}$
- Irreducible  $Z(\nu \bar{\nu}) + \gamma$

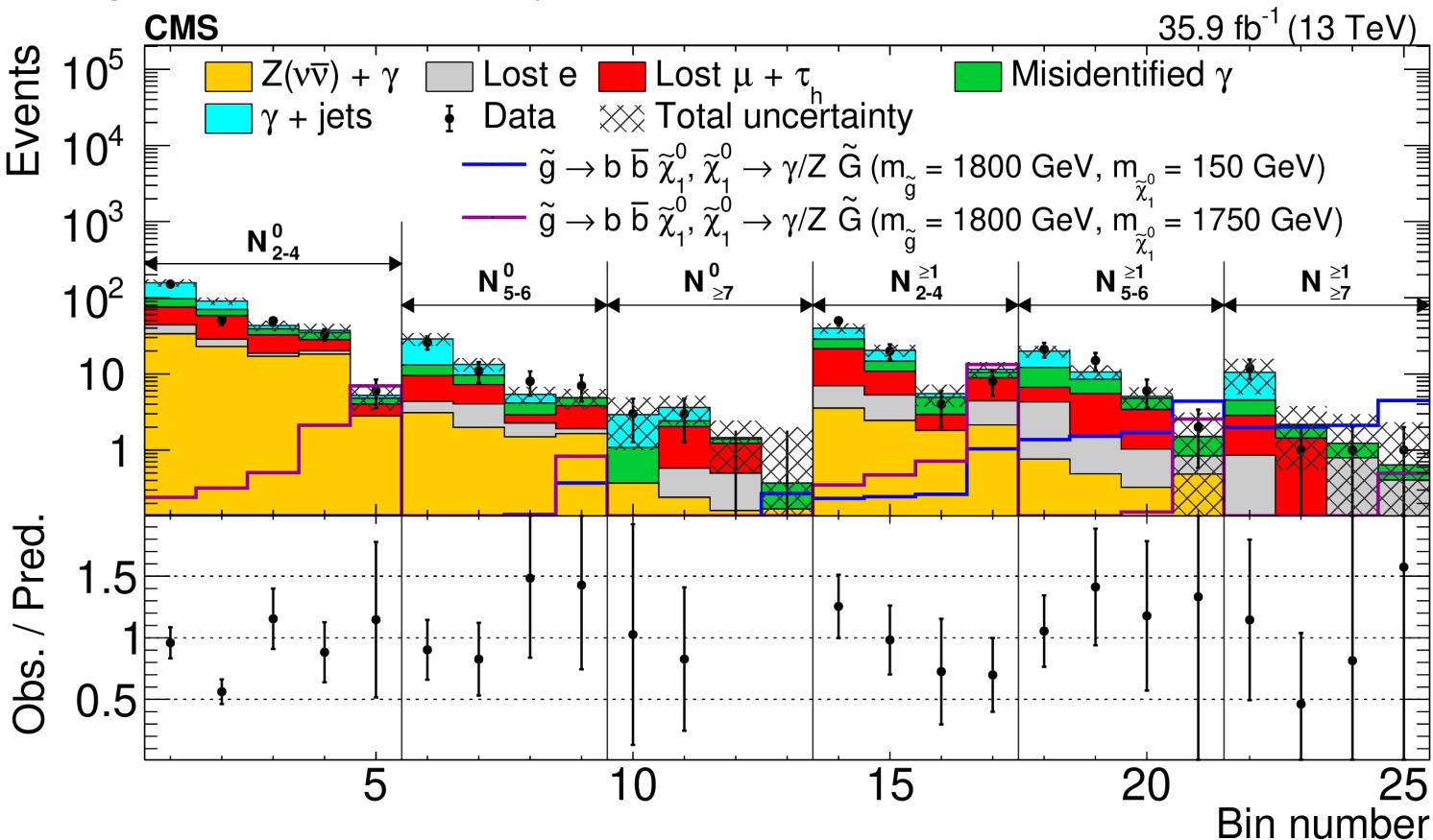
[CMS-SUS-18-002](#)



# Stop with GMSB

- Search region is binned in  $p_T^{\text{miss}}$ , number of jets and number of b-tagged jets ( $N_j^b$ )
- No significant excess beyond SM

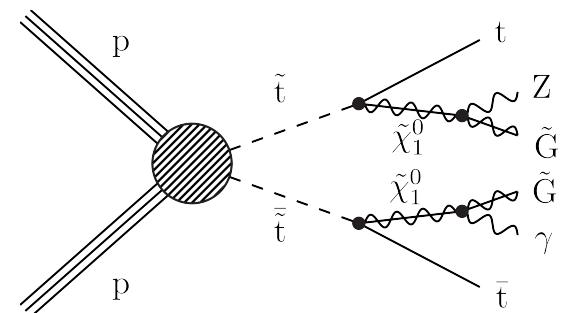
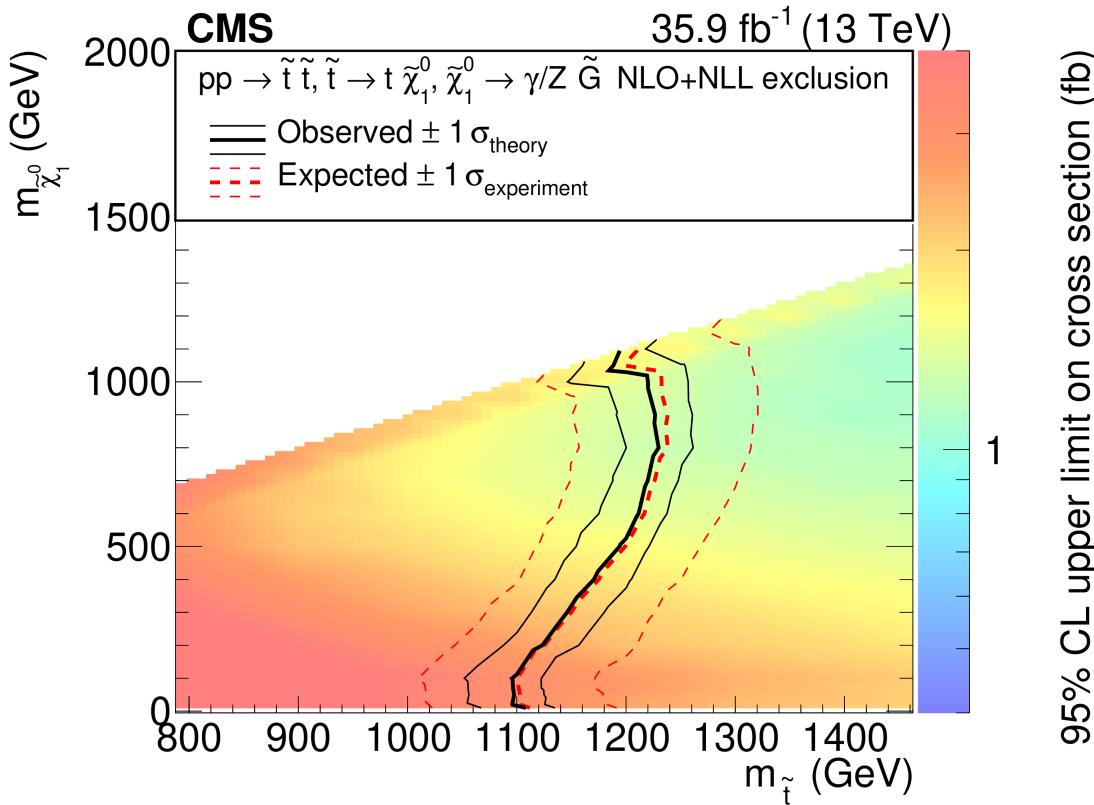
[CMS-SUS-18-002](#)



# Stop with GMSB

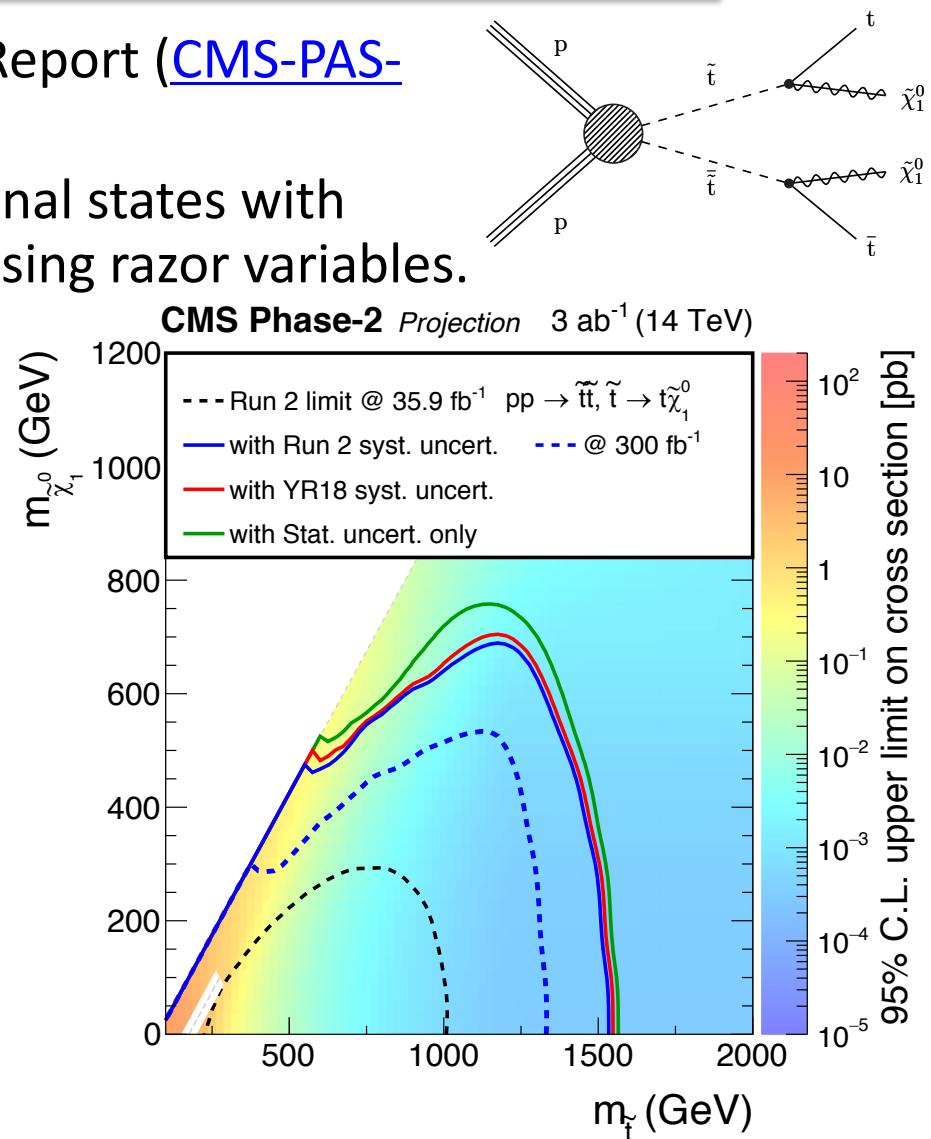
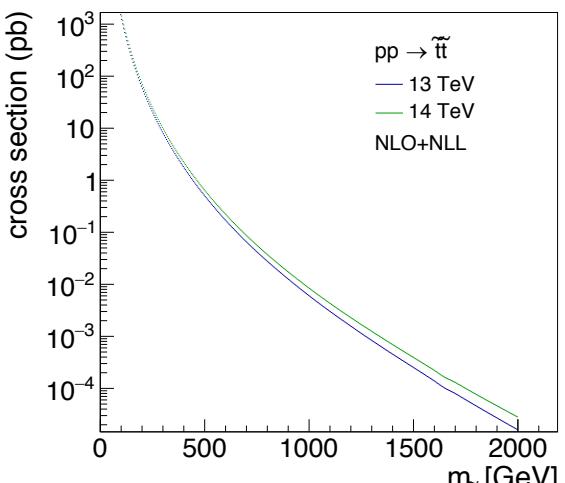
- Exclusion on stop mass up to 1230GeV

[CMS-SUS-18-002](#)

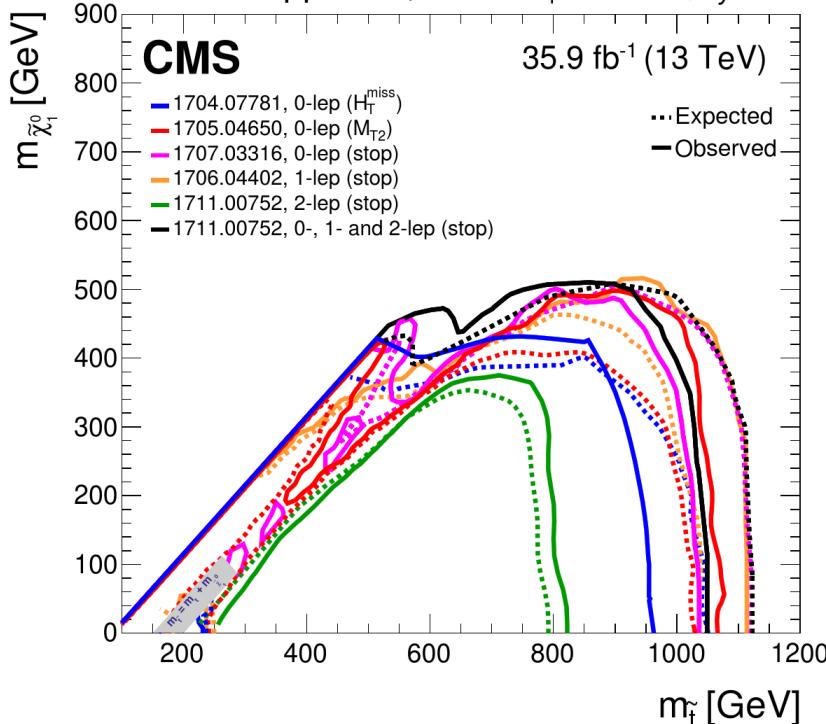


# Projected Reach @HL-LHC

- Future projection in CERN Yellow Report ([CMS-PAS-FTR-18-037](#))
- Base on run 2 search in hadronic final states with boosted W bosons or top quarks using razor variables. ([JHEP 03 \(2019\) 031](#))
- Exclusion limit reach up to 1.5TeV for stop pair production @HL-LHC



# Summary

- Robust performance of LHC during Run 2, CMS collected 137/fb integrated luminosity
  - Early hadronic analysis with full Run 2 exclude sbottom and stop up to  $\sim 1.2\text{TeV}$
  - More analysis to cover the phase space and new SUSY models
- $\text{pp} \rightarrow \tilde{t}\bar{t}, \tilde{t} \rightarrow t \tilde{\chi}_1^0$  July 2018
- $35.9 \text{ fb}^{-1} (13 \text{ TeV})$
- $m_{\tilde{\chi}_1^0} [\text{GeV}]$
- $m_{\tilde{t}} [\text{GeV}]$
- 
- Legend:
- 1704.07781, 0-lep ( $H_T^{\text{miss}}$ )
  - 1705.04650, 0-lep ( $M_{T2}$ )
  - 1707.03316, 0-lep (stop)
  - 1706.04402, 1-lep (stop)
  - 1711.00752, 2-lep (stop)
  - 1711.00752, 0-, 1- and 2-lep (stop)
- ...Expected — Observed
- Direct stop searches in various final states and phase space are on the pipeline. Stay tune!
  - A search for Stop with tau final states from [Soham](#) this Wednesday

CMS Public SUSY Result: <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS>