

# Searches for third generation SUSY particles

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on behalf of the ATLAS and CMS collaborations

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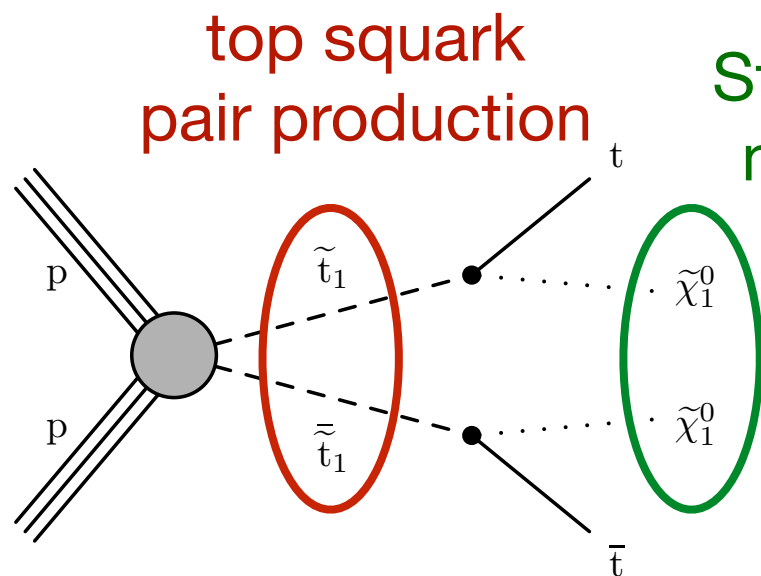
# Motivation

Light 3<sup>rd</sup> generation squarks with mass around the TeV scale well motivated:

- Cancel loop corrections to Higgs mass
- Squarks carry color charge → sizable x-sec at 13 TeV
- Decay via 3<sup>rd</sup> generation SM quarks or leptons → distinctive final states

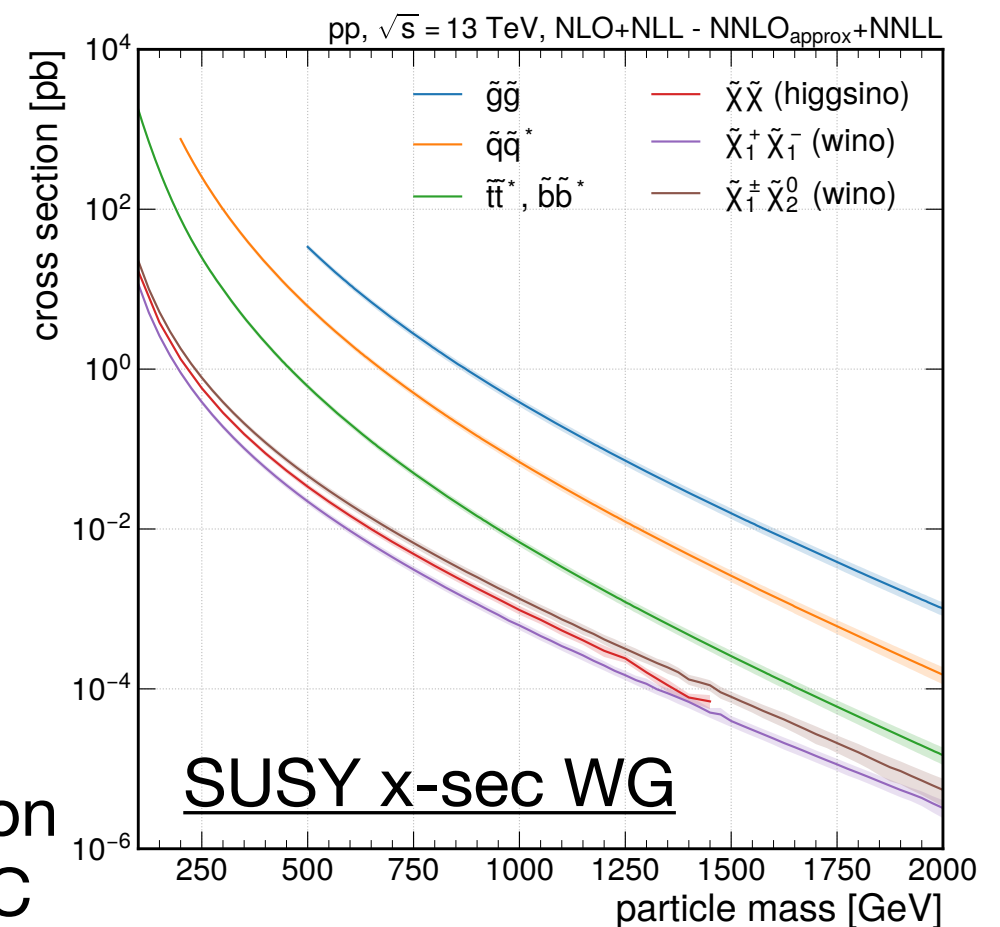
Many dedicated and inclusive efforts to search for stops and sbottoms during LHC Run 2: large data set, new tools, closed holes!

## Simplified models



Lightest neutralino:  
Stable, weakly interacting &  
massive → DM candidate

Sizable production  
x-sec at the LHC

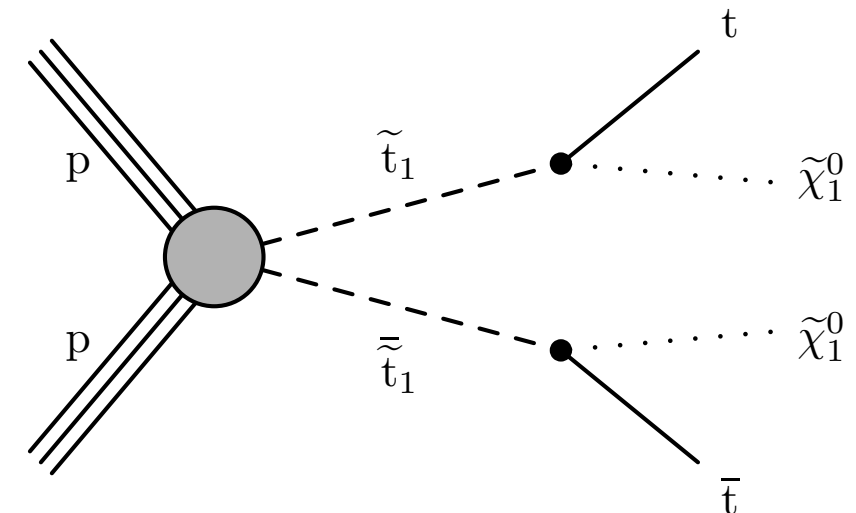


# Direct top squark production

Top squark pair production with prompt decay leads to variety of final states: 0, 1 or 2 leptons

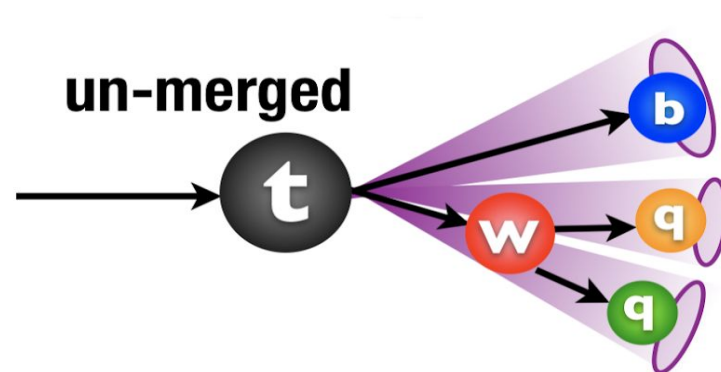
- Largest signal branching fraction into **all hadronic final state** (hadronic top decays)
- Facilitate novel tools like **top quark tagging** to enhance sensitivity to signals with moderate to high boost

arXiv: 2103.01290

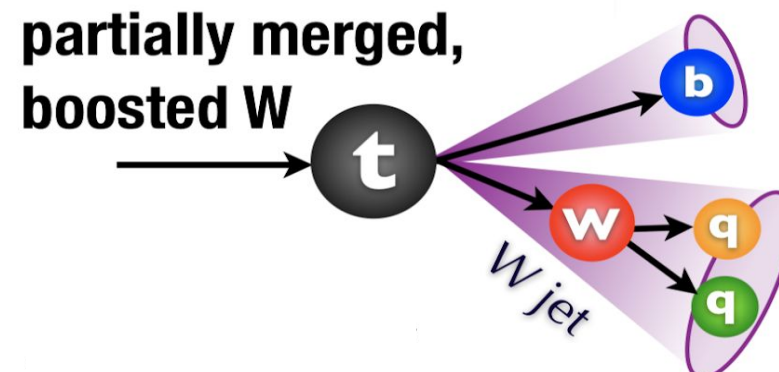


+ many more simplified models of top squark production

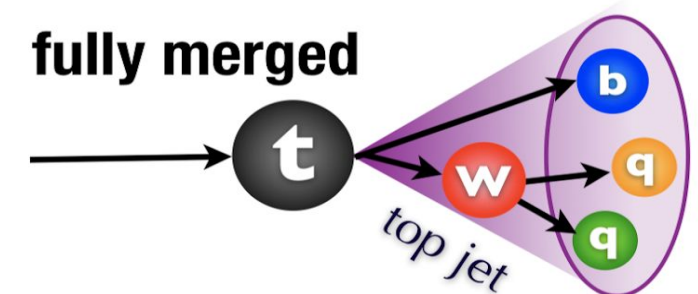
top quark with  $p_T \geq 450$  GeV



resolved top  
from 3 AK4 jets

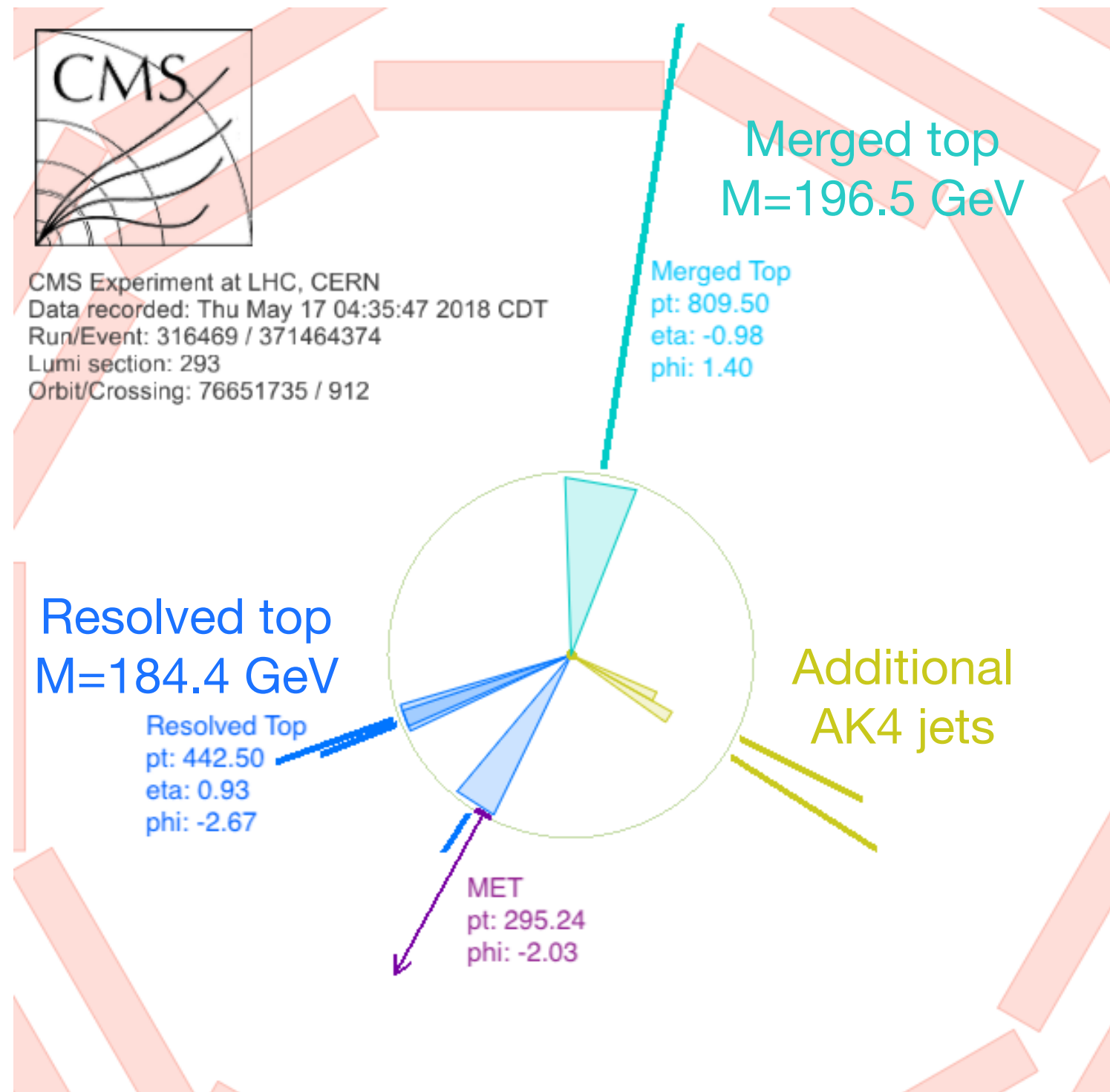


merged W in  
AK8 jet



merged top in  
AK8 jet

# Top taggers in action

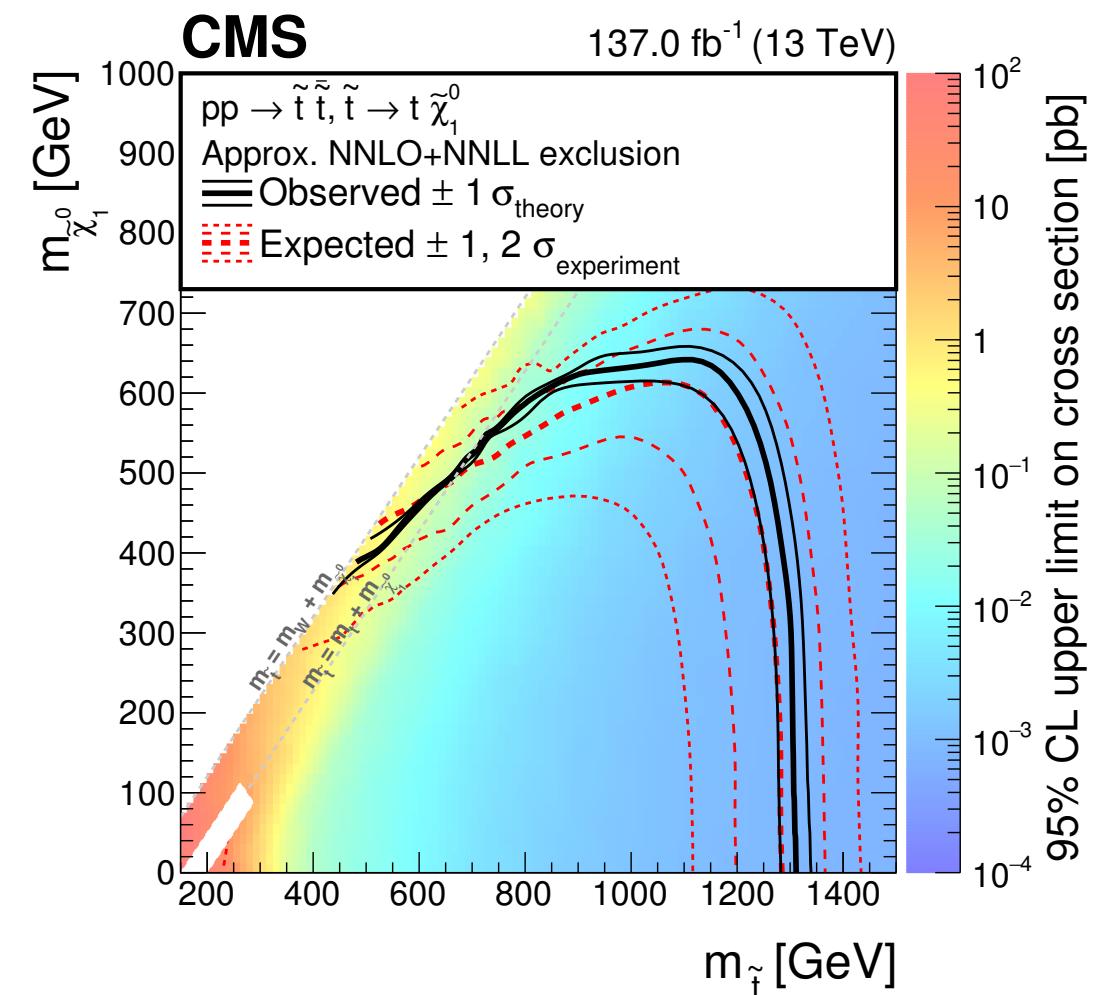
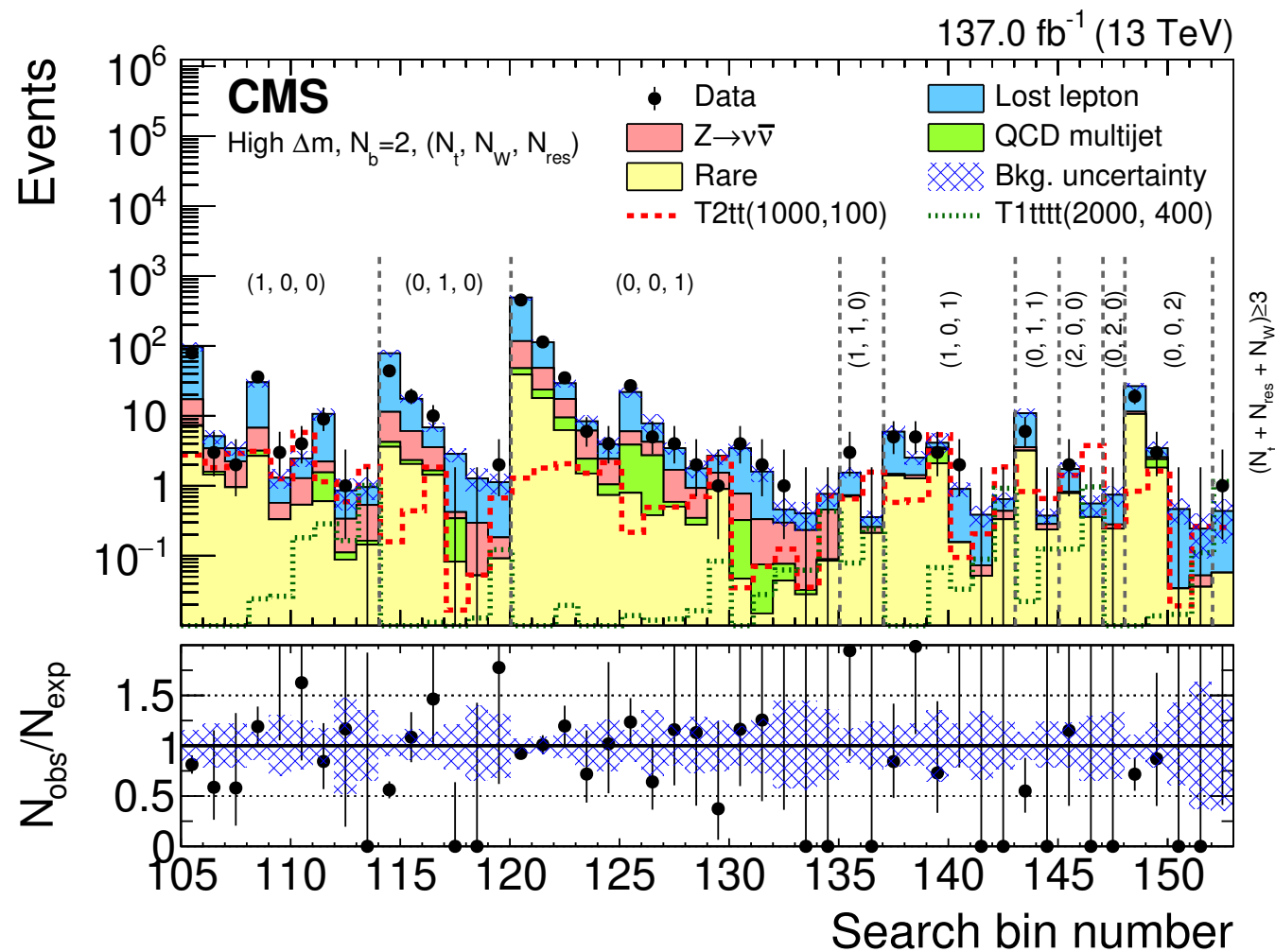




# Direct top squark production

Inclusive analysis design for sensitivity to variety of signal models (e.g. different  $\Delta m$  between stop and LSP)  $\rightarrow$  large amount of signal regions

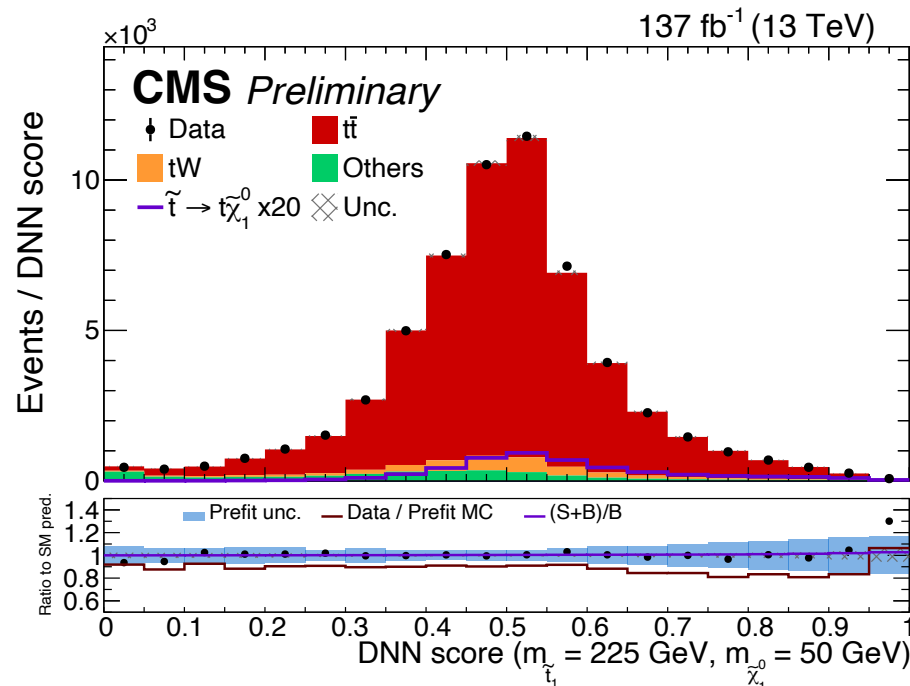
- Top and W taggers used in high  $\Delta m$  regions, significantly reduce backgrounds from SM processes with lost lepton
- Sensitive to top squark masses up to 1.3 TeV



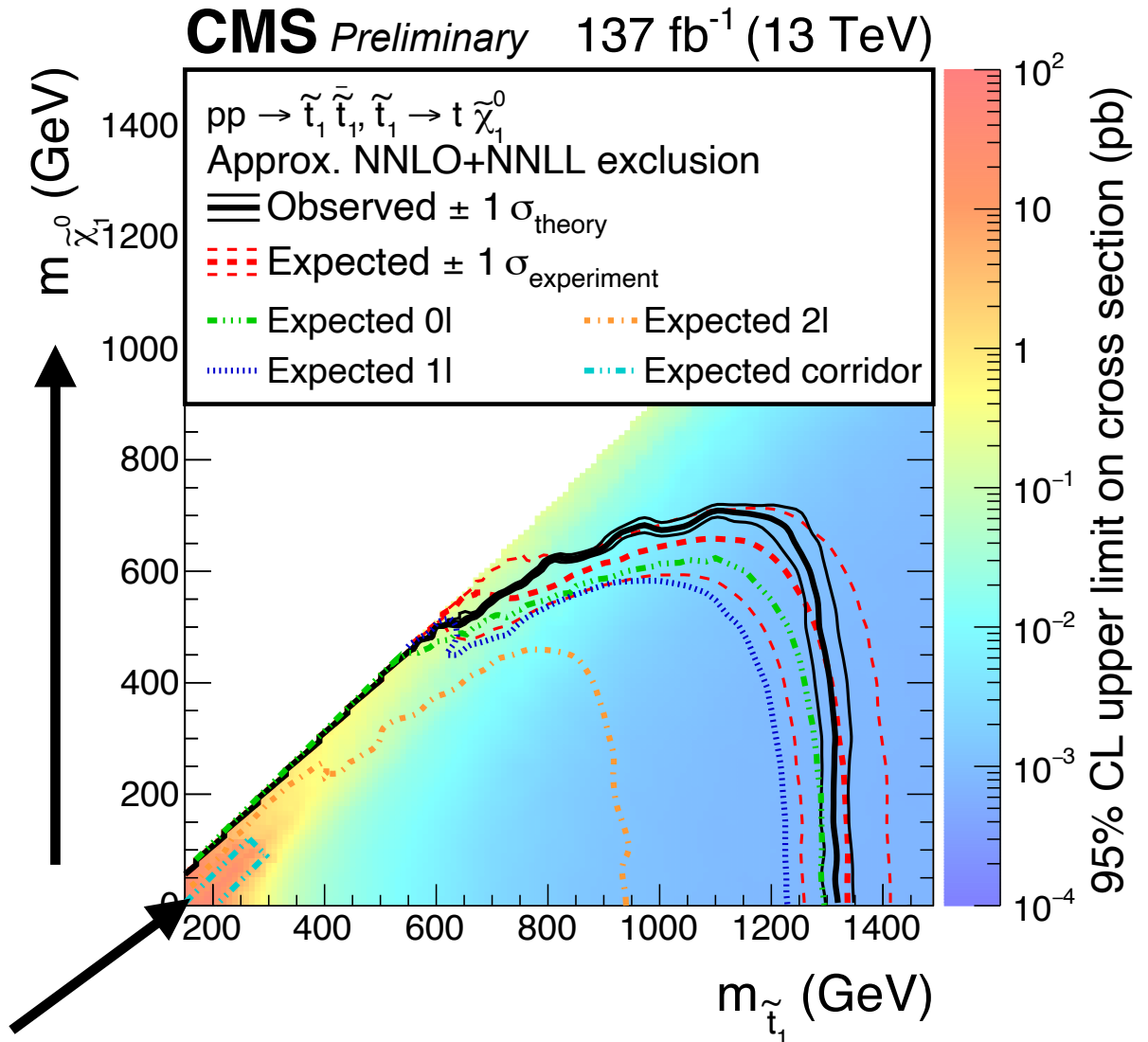
# CMS stop combination

Combination of published analysis in 0, 1 and 2 lepton final state

- Exclude top squarks up to 1350 GeV in certain simplified models
- Corridor with high level of signal/SM  $t\bar{t}b\bar{a}$  degeneracy targeted with dedicated analysis
- Also: Best sensitivity to  $t\bar{t}$ +DM (backup)!



improvement by  
~200 GeV wrt 2016,  
~400 GeV wrt Run 1



Dedicated NN based analysis: top corridor fully excluded at 95% CL

pushed limits by ~300 GeV wrt 2016, ~500 GeV wrt Run 1

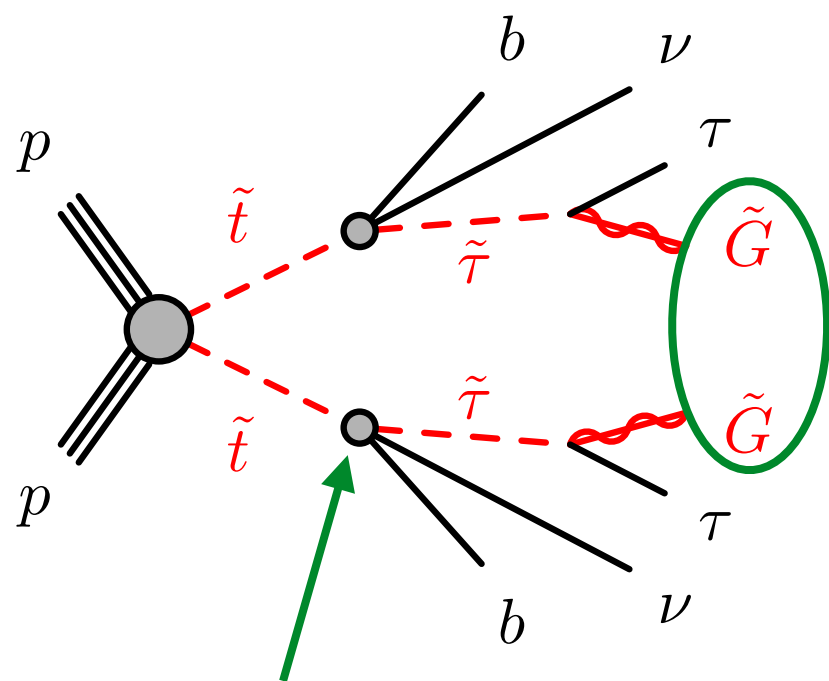
Poster session: Andrea's poster about the corridor analysis

CMS-PAS-SUS-20-002

# Stops with taus

JHEP 05 (2021) 093

Taus often not part of search strategies  
 → reduced sensitivity to models with preferred coupling 3<sup>rd</sup> gen leptons.  
**Simplified GMSB model** with two parameters: stop and stau mass

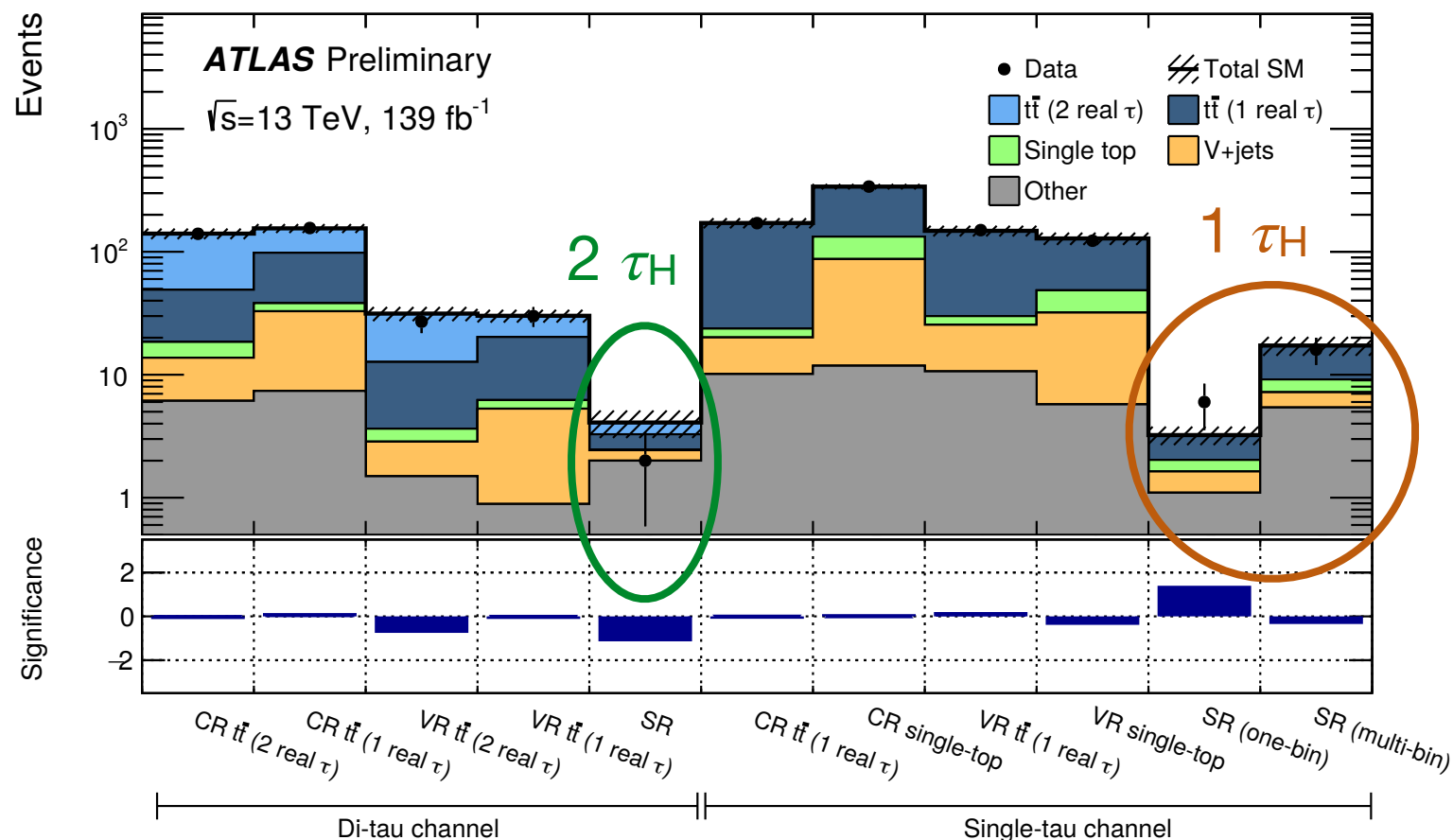


$\tilde{\tau} \rightarrow \tau \nu b$  3-body decay via off-shell chargino,  $\tilde{\tau}$  is the NLSP

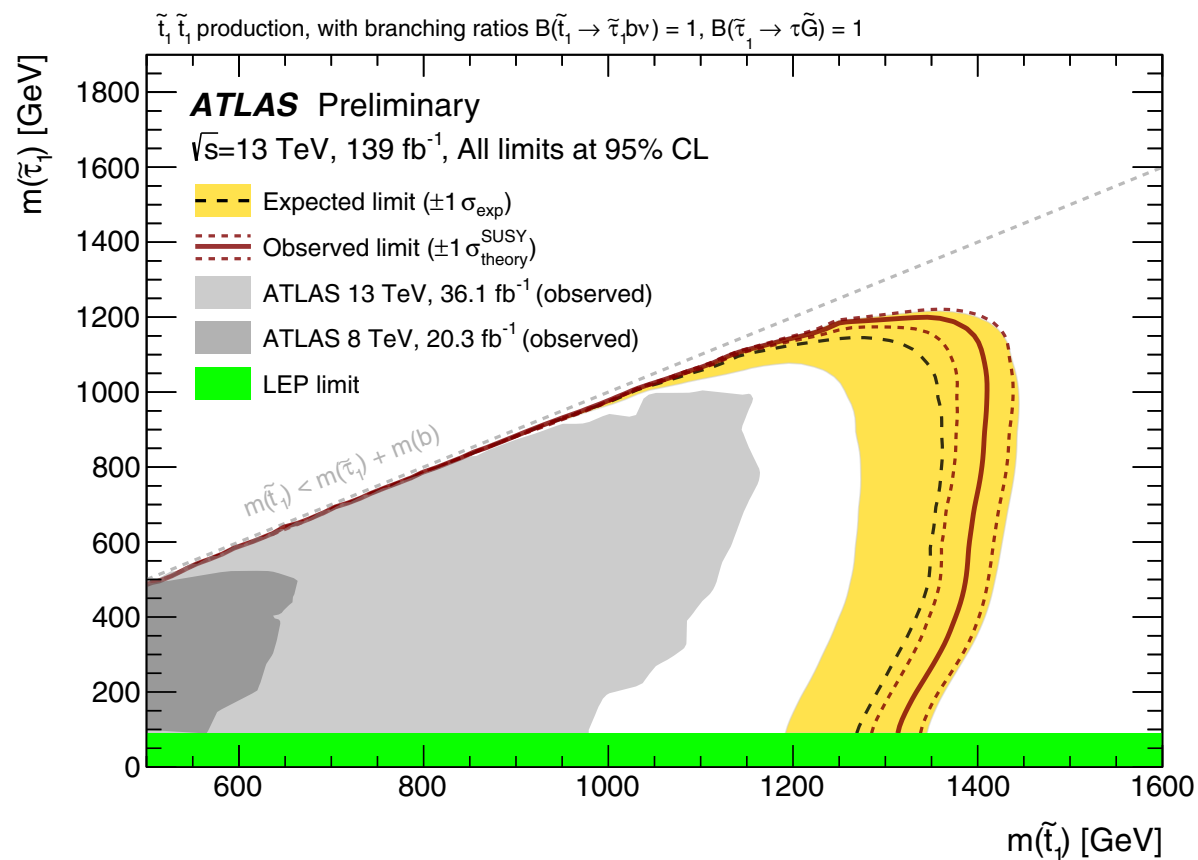
Experimental signature: b-tagged jets, hadronic taus and  $p_T^{\text{miss}}$

**GMSB model: (almost) massless gravitino is LSP**

If stau is light (low mass splitting between NLSP and LSP): tau can escape detection → single- $\tau$  channel for enhanced sensitivity

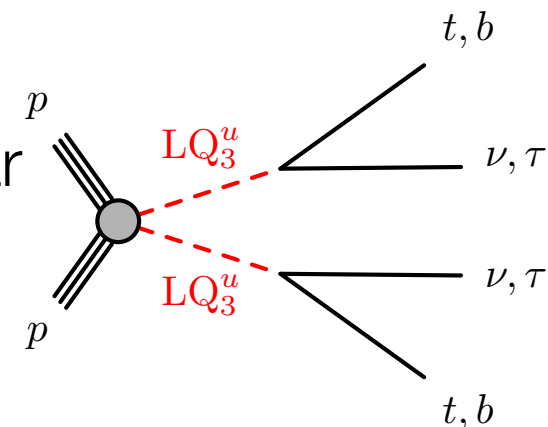


# Interpretations

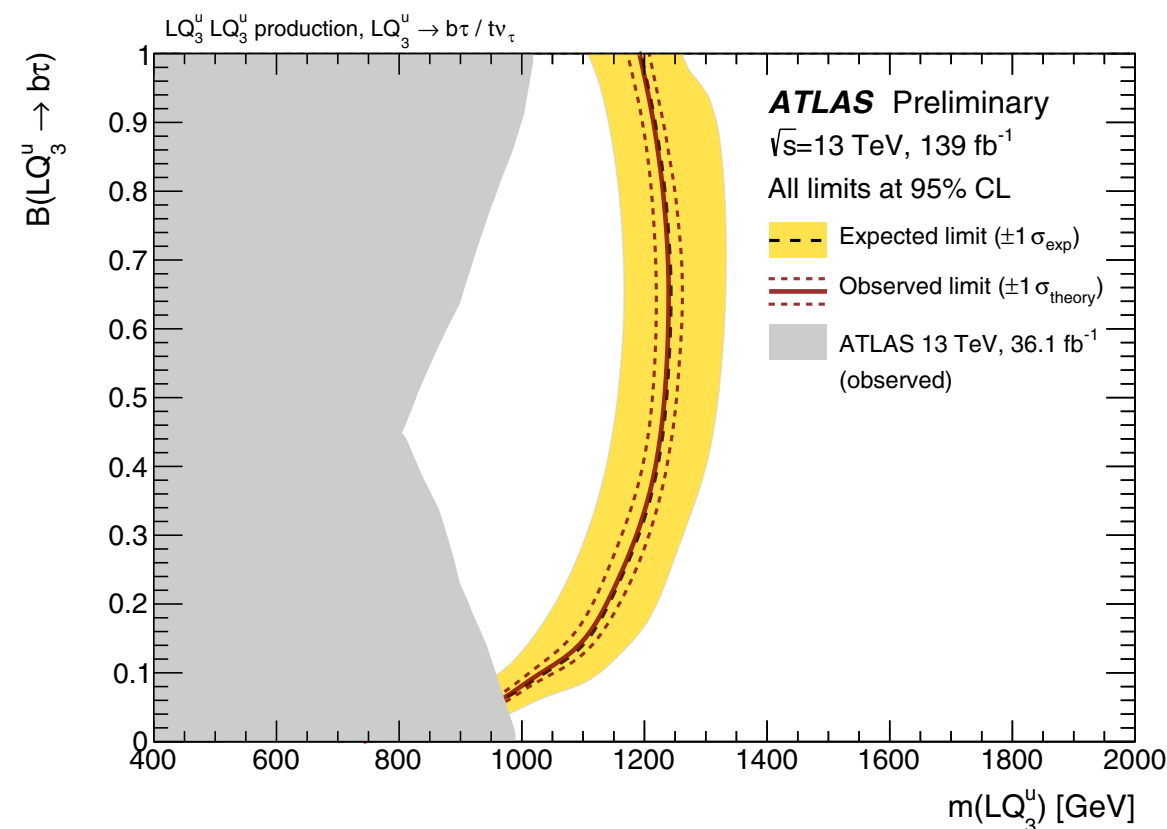


- Scan in 2 mass dimensions, sensitivity drops at low stau mass
- Extend previous limits by around 300 GeV
- High stop mass sensitivity driven by di- $\tau_H$  channel

Similar final state from  
**Leptoquarks**  $\rightarrow$  popular model to explain flavor anomalies

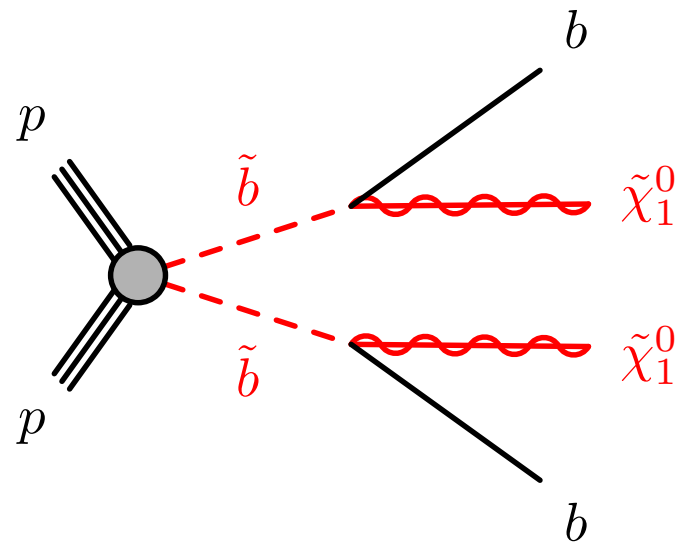


Di- $\tau_H$  channel not optimized for this signal  
 $\rightarrow$  only single- $\tau_H$  signal regions used.



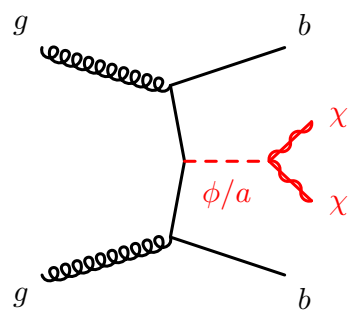
CMS result: [2012.04178](#)

# Searches for bottom squarks

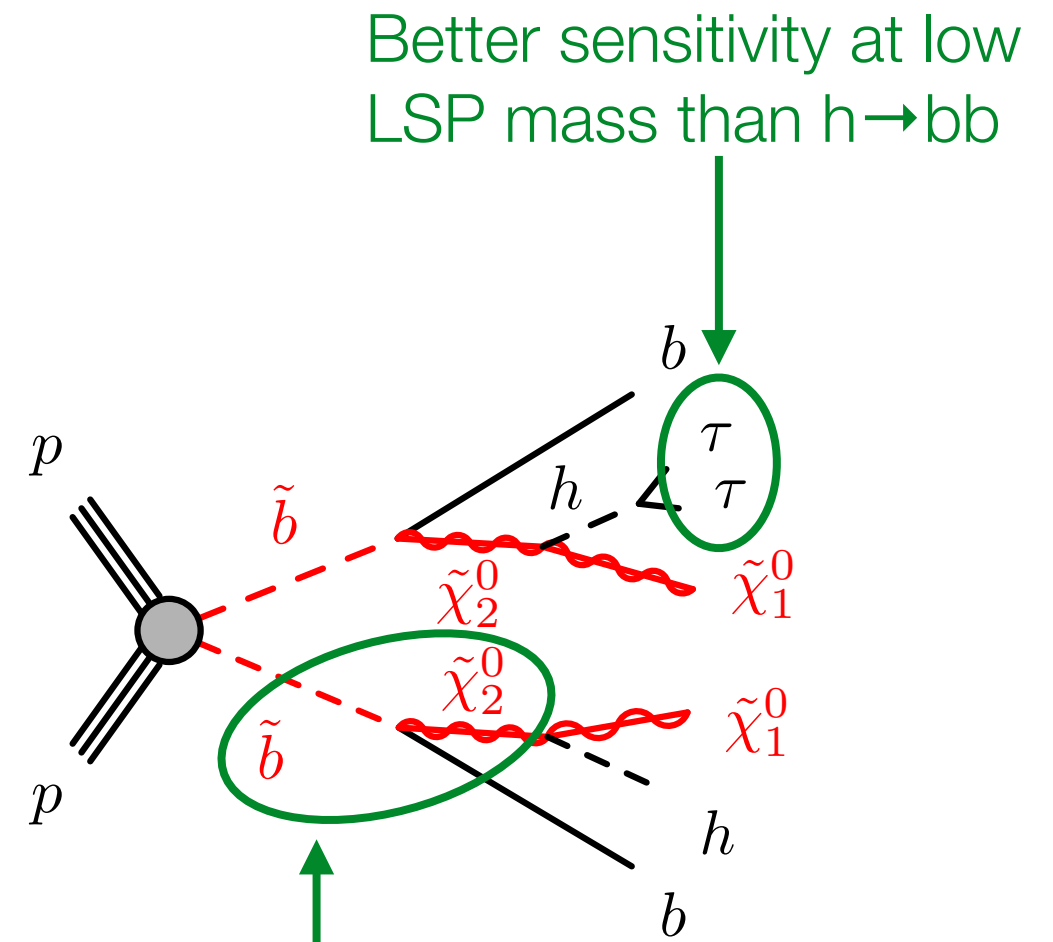
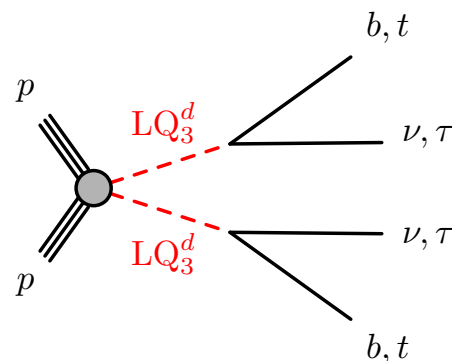


Simplified model of **direct bottom squark pair production** with two parameters: sbottom and neutralino mass.  
All-hadronic b-jet +  $p_T^{\text{miss}}$  searches only, but variety of models with similar final state

bb+DM



Leptoquark



Better sensitivity at low LSP mass than  $h \rightarrow b\bar{b}$

Enhanced if  $\tilde{b}$  mostly partner of left-chiral b, wino-like  $\tilde{\chi}_2^0$  and bino-like  $\tilde{\chi}_1^0$

$\tilde{\chi}_2^0 \rightarrow h\tilde{\chi}_1^0$  and  $h \rightarrow \tau\tau$  yield similar final state as before, but with resonant tau production

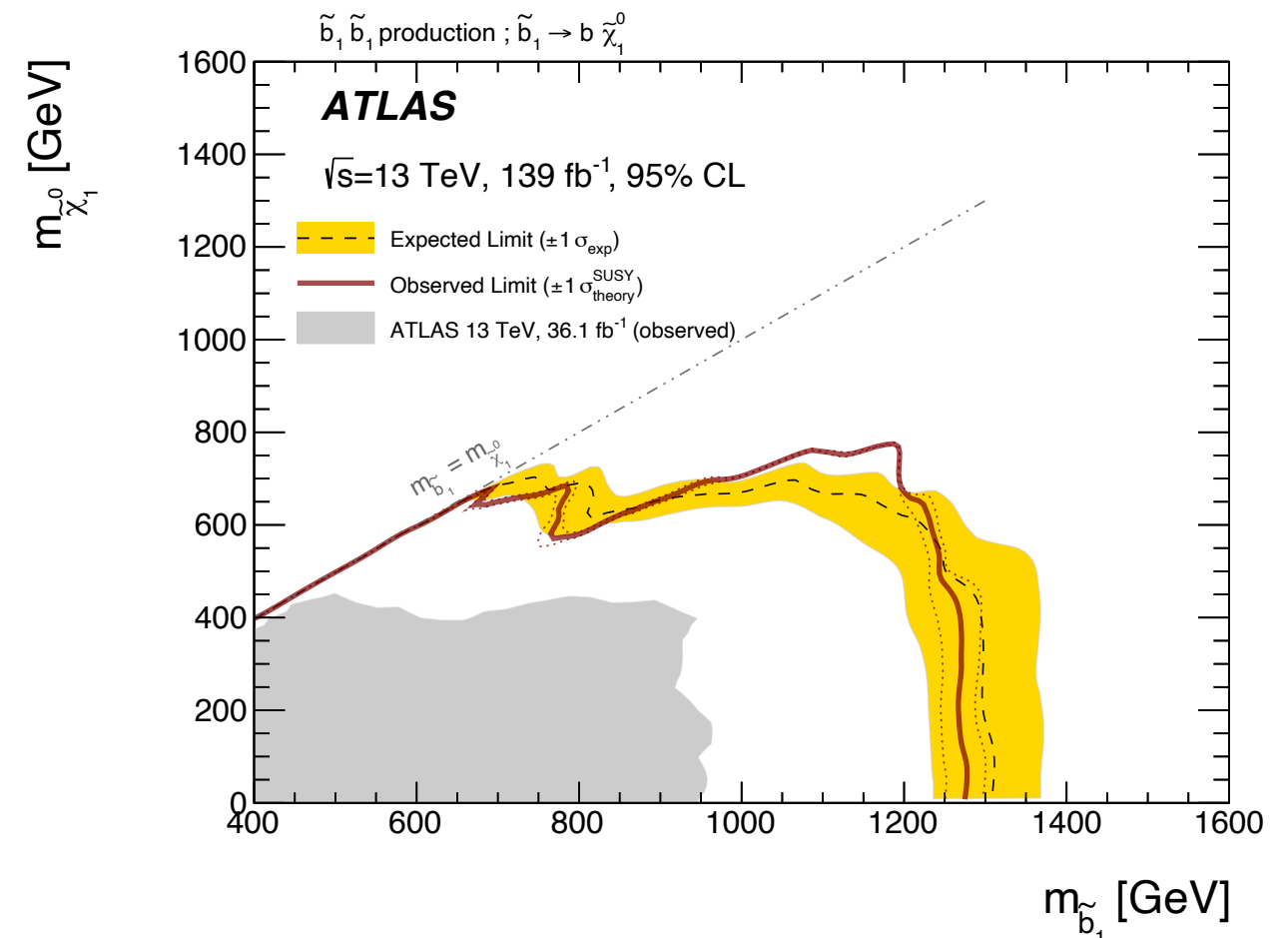
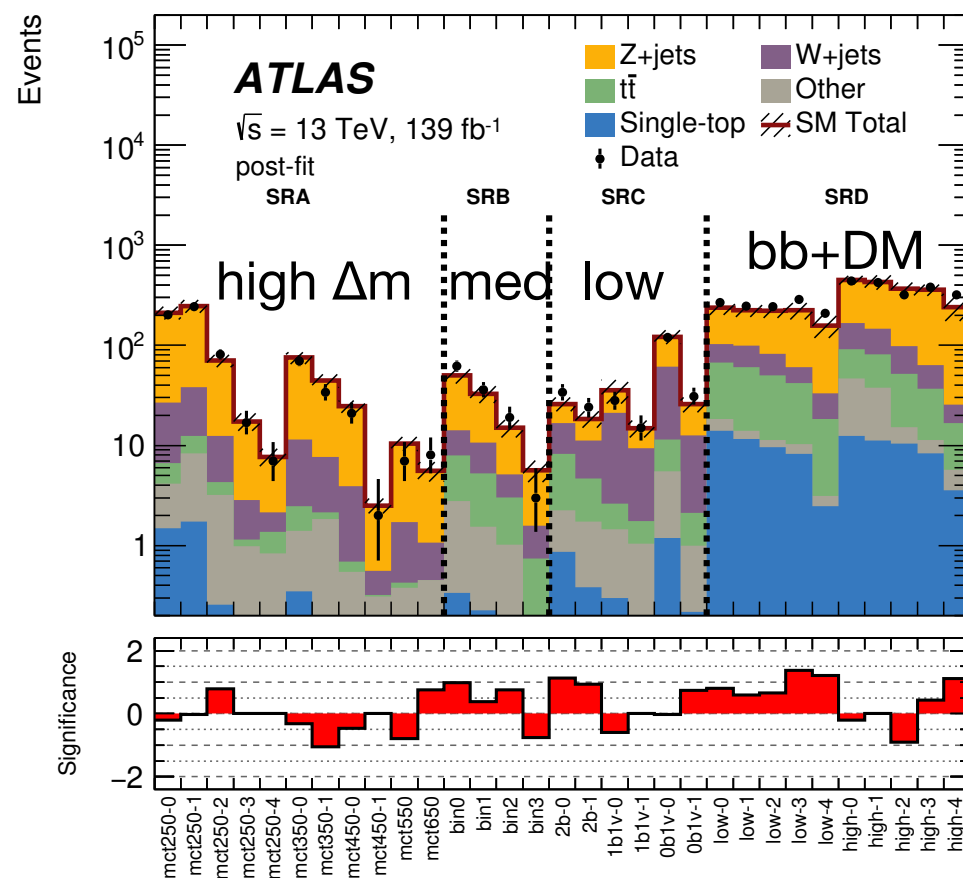
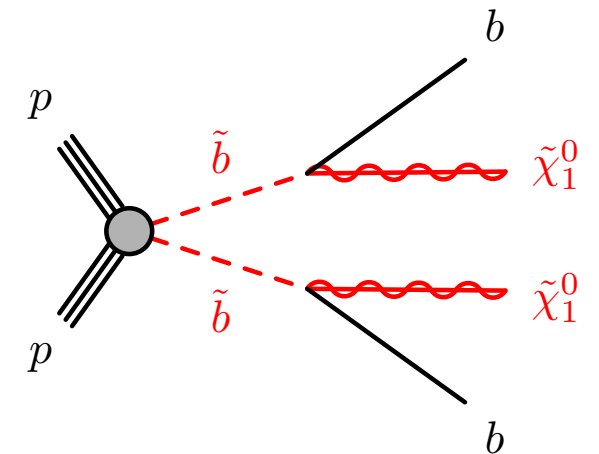


# Direct sbottom decay model

Mass splitting between sbottom and LSP defines kinematics → dedicated non-overlapping signal regions for low, medium and high  $\Delta m$

- High  $\Delta m$ : events with high  $p_T^{\text{miss}}$ ,  $m_{bb}$ ,  $m_{CT}$  and  $m_{\text{eff}}$
- Medium  $\Delta m$ : BDT based on mix of low and high level inputs
- Low  $\Delta m$ : ISR jets and dedicated identification of soft b quarks

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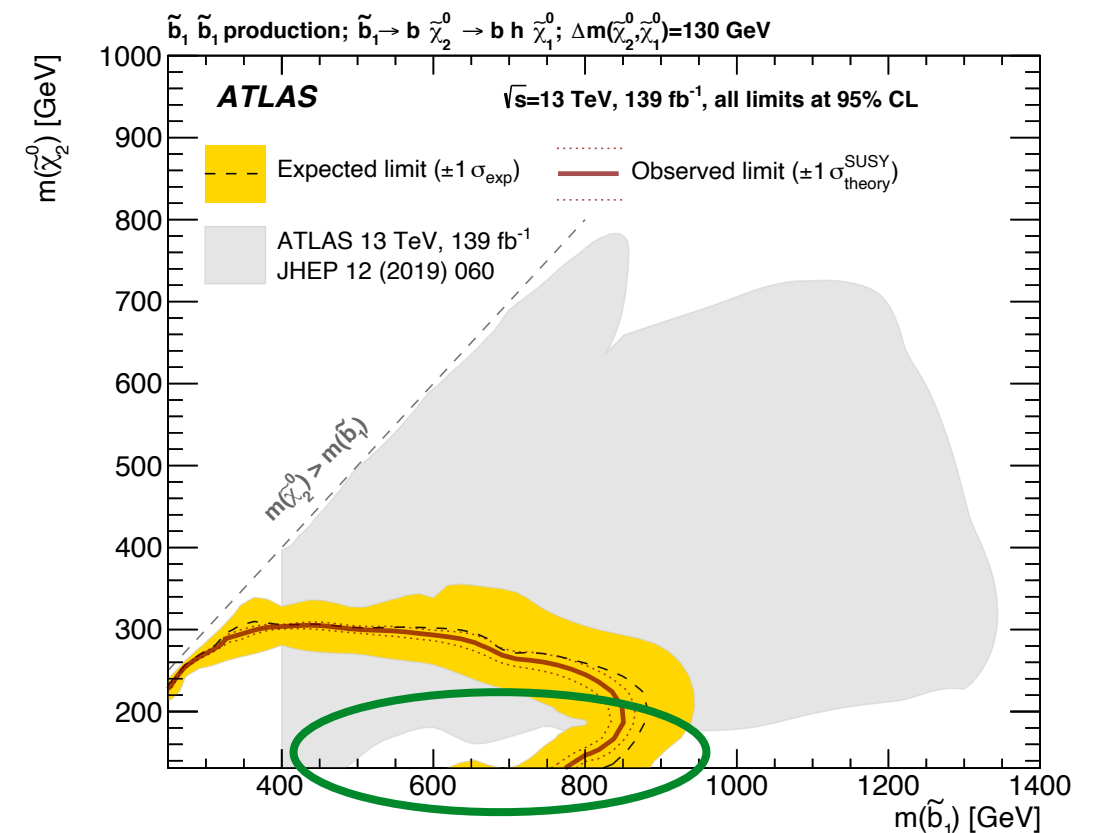
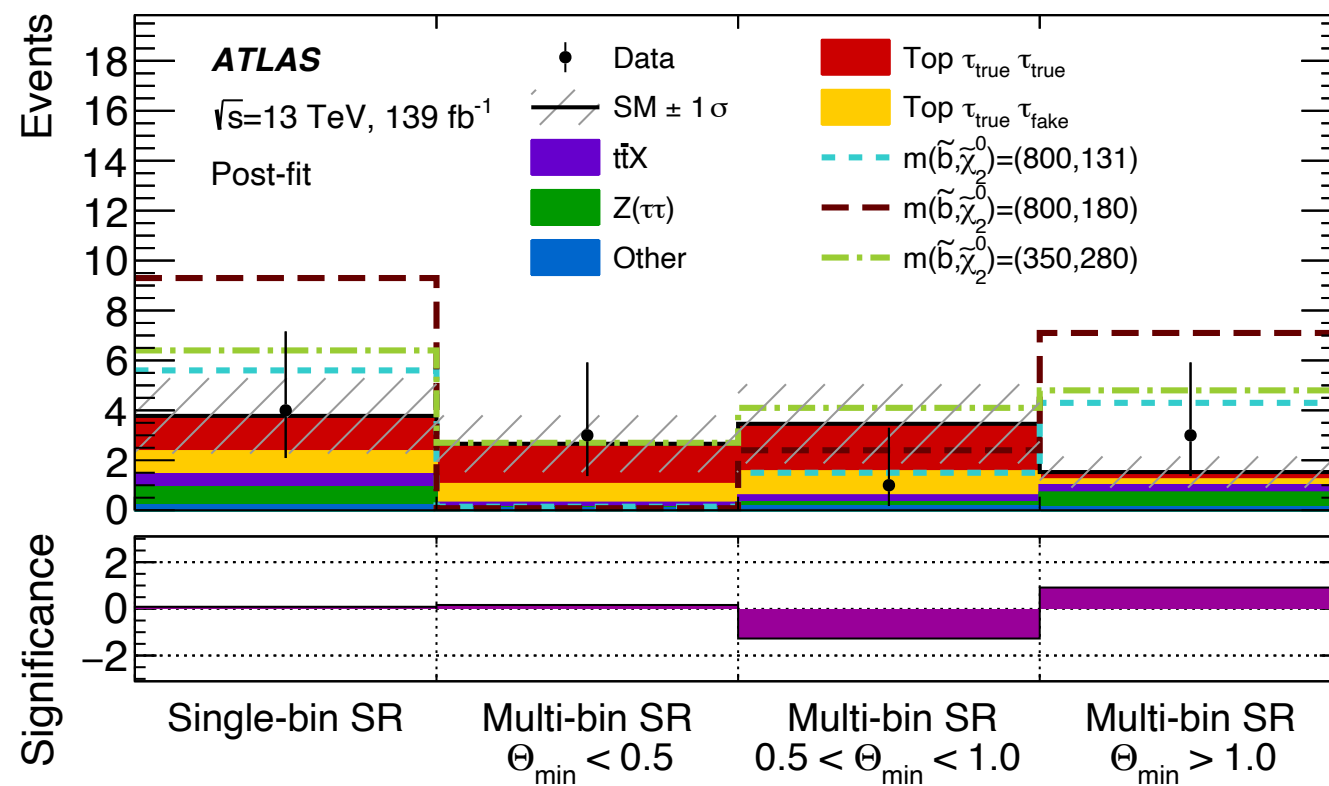
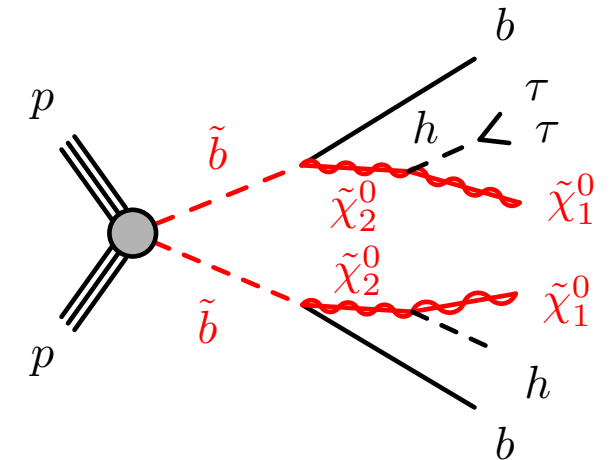


# Sbottom with taus

arXiv: 2103.08189

Very similar final state as in stop-stau model, but resonant taus from  $h \rightarrow \tau\tau$

- Assume SM Higgs boson mass and  $B(h \rightarrow \tau\tau)$
- Minimum solid angle of b-jet and  $\tau_H$  pairs  $\Theta_{\min}$  to discriminate against SM top quark background
- Single bin SR for reinterpretations



Enhanced sensitivity wrt  $h \rightarrow b\bar{b}$

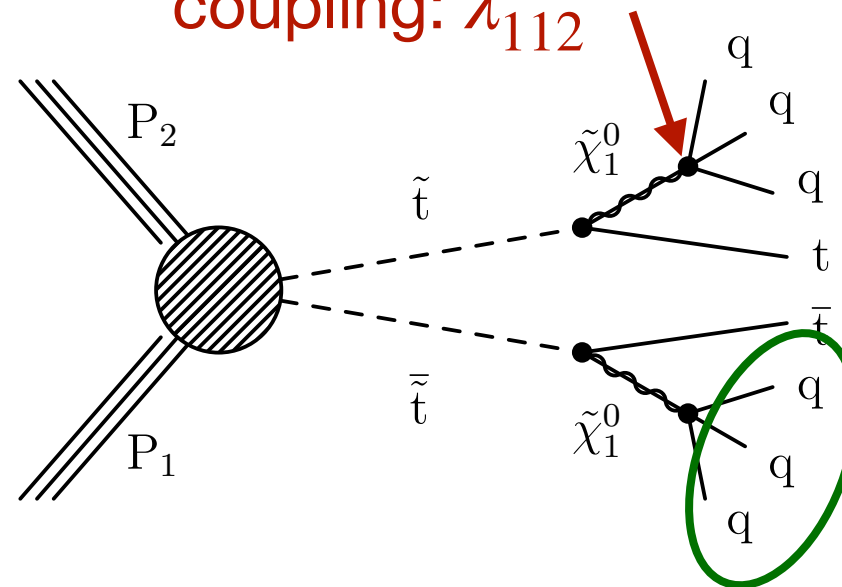
# Stops w/o $p_T^{\text{miss}}$ signature: RPV and stealth

Stealth stop, R-parity violating models could explain absence of  $p_T^{\text{miss}}$  signals  $\rightarrow$  dedicated search:

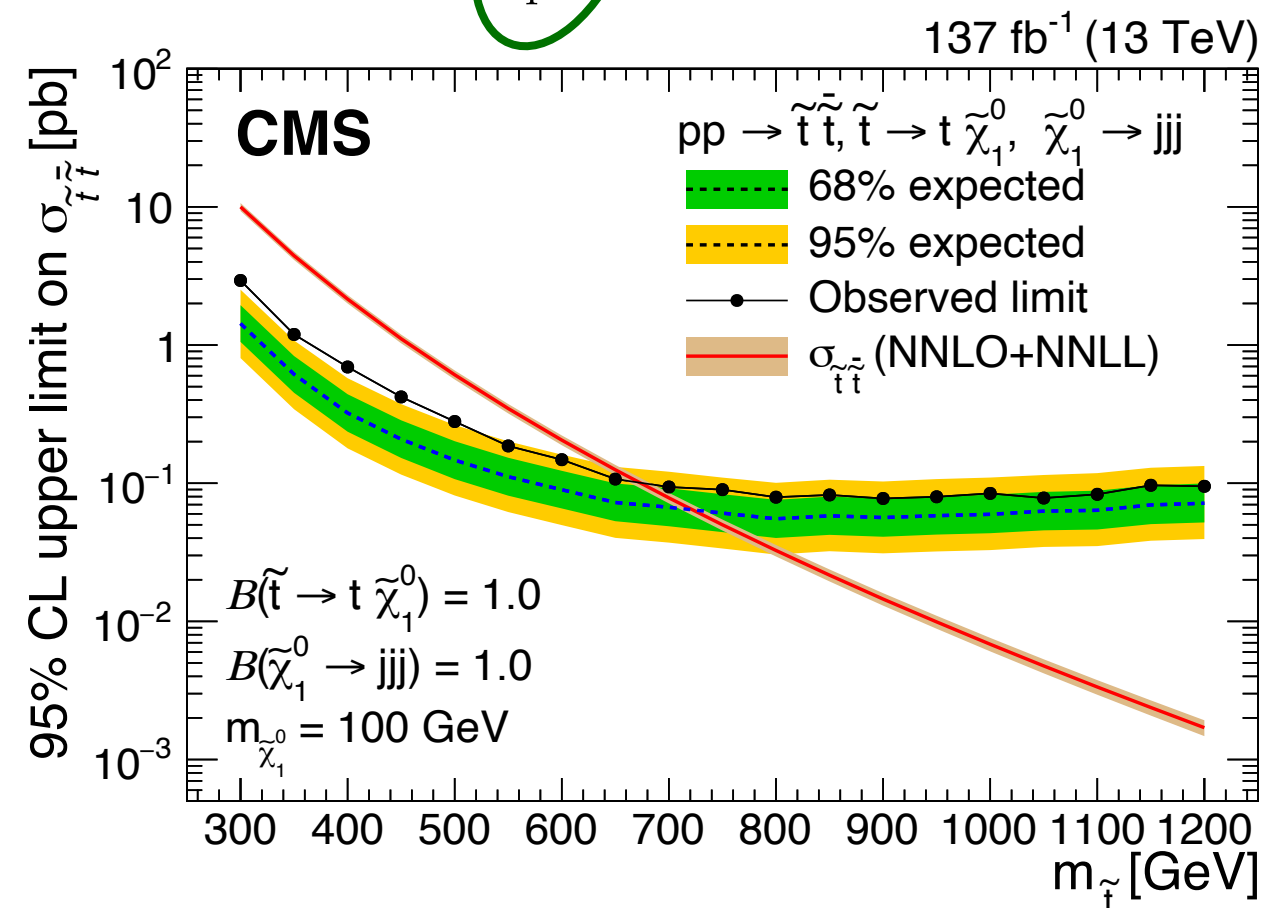
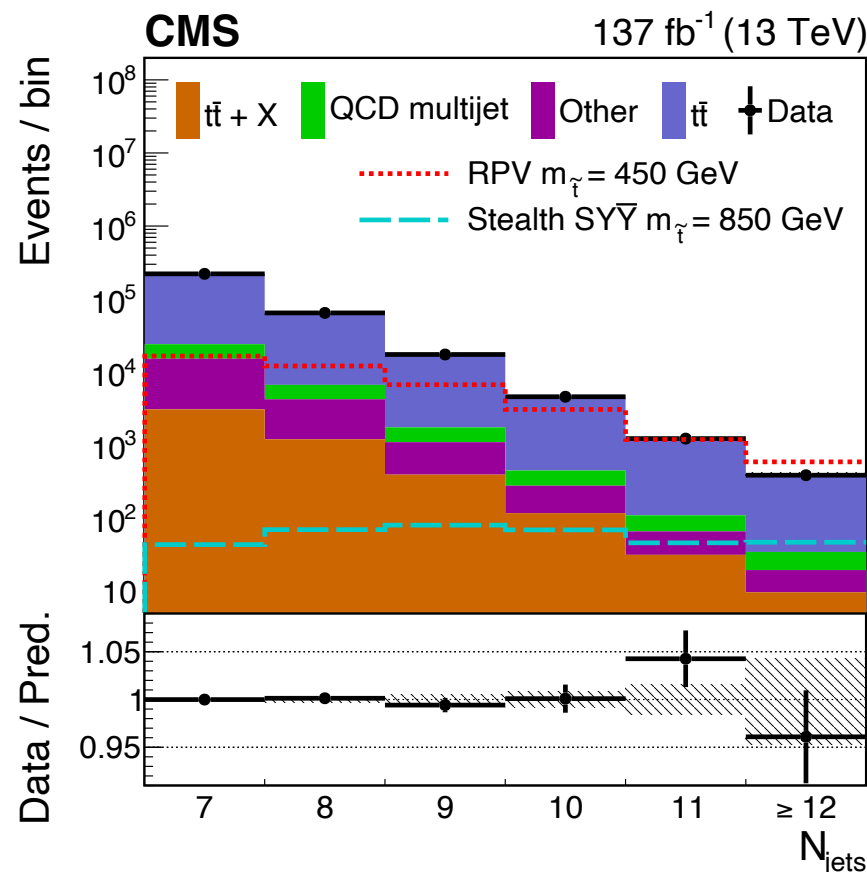
- $N_{\text{jets}}$  instead of  $p_T^{\text{miss}}$
- Jet scaling function used for data-driven background estimates

Baryon number violating UDD  
coupling:  $\lambda''_{112}$

arXiv: 2102.06976

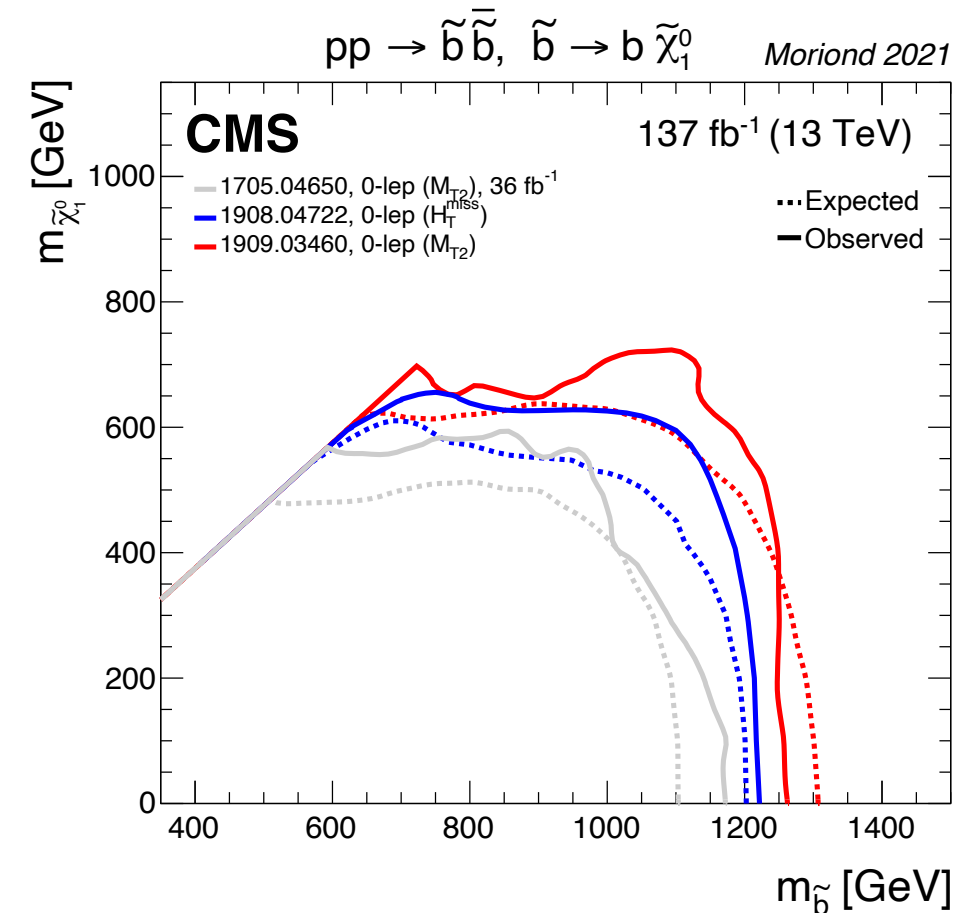
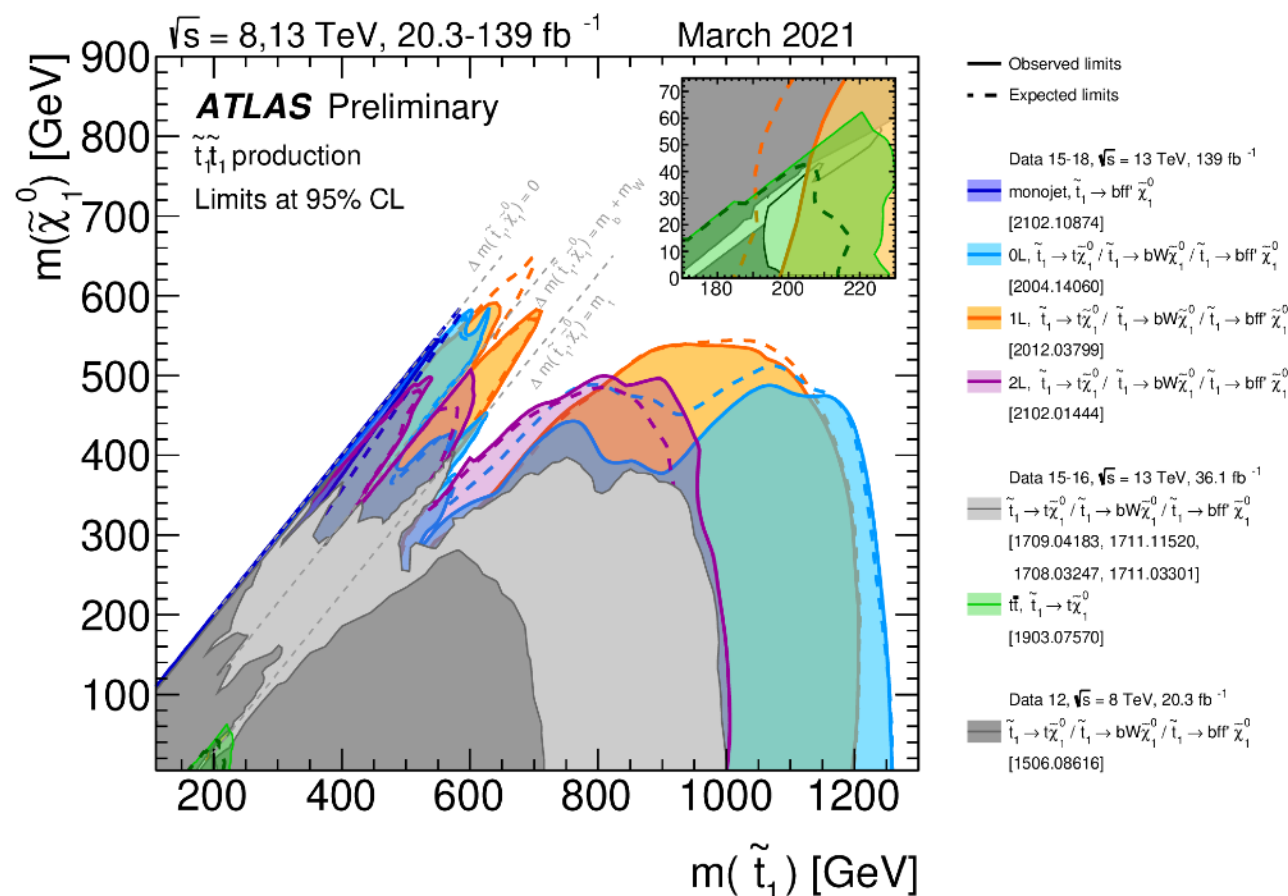


Here: up, down, strange



# Summary

- ATLAS and CMS released large set of results using the LHC Run 2 data
  - Natural stops and sbottoms below 1.2 TeV (or even higher) excluded in wide range of simplified models
- Similarly strong limits at TeV scale for cascade decays of stops/sbottoms, GMSB models, RPV or stealth stops
- New analysis techniques increase sensitivity beyond luminosity scaling



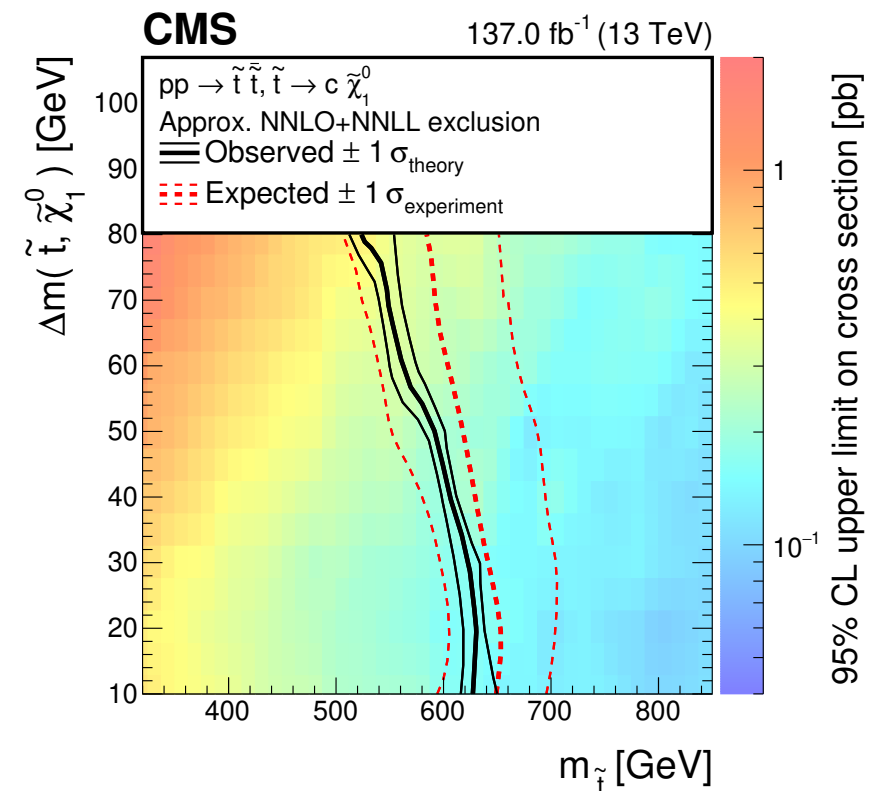
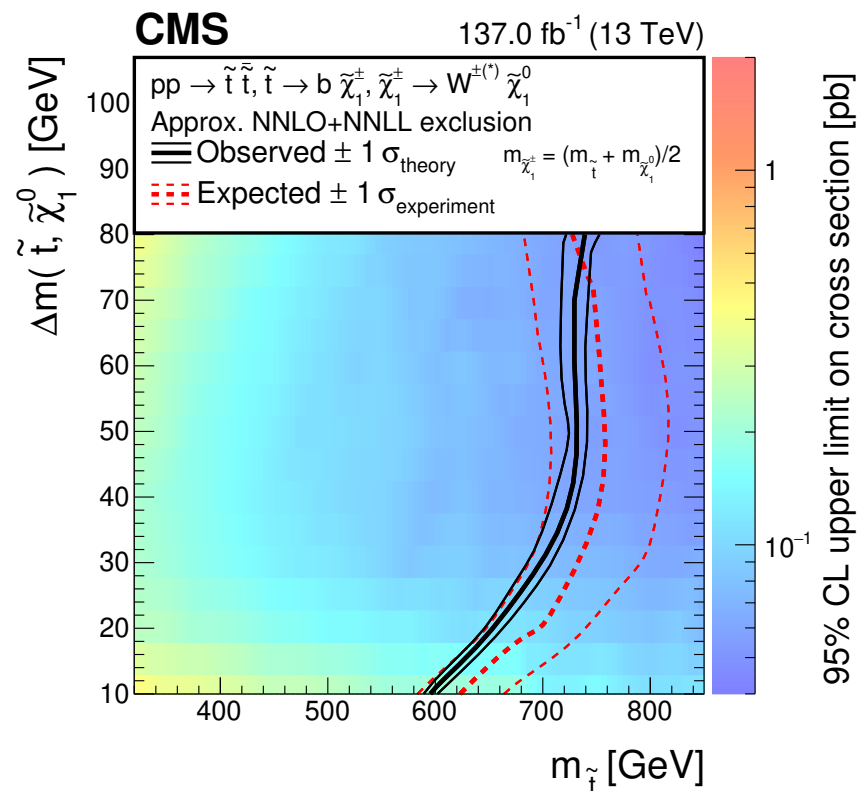
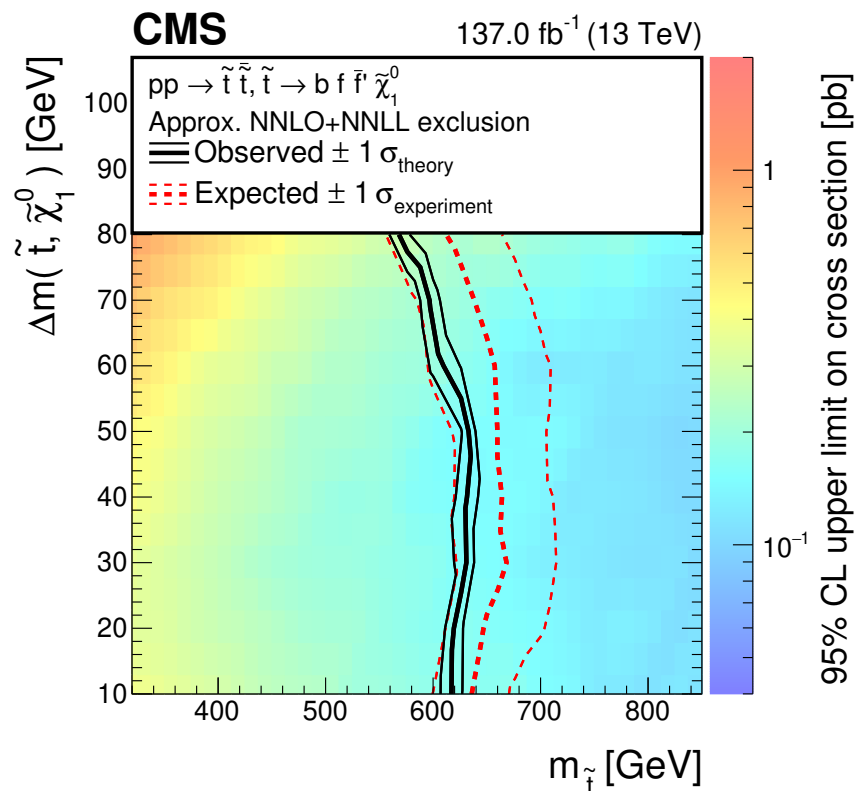
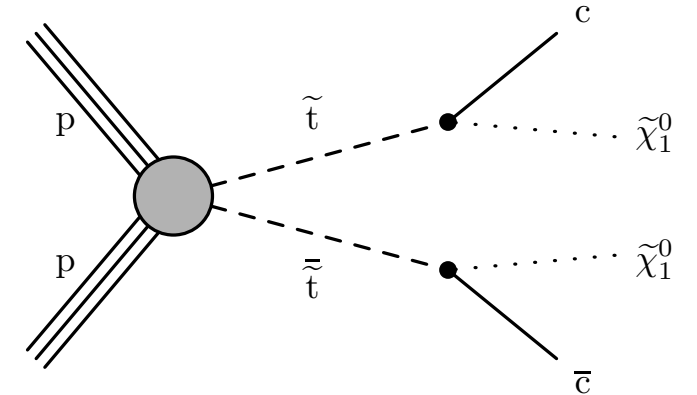
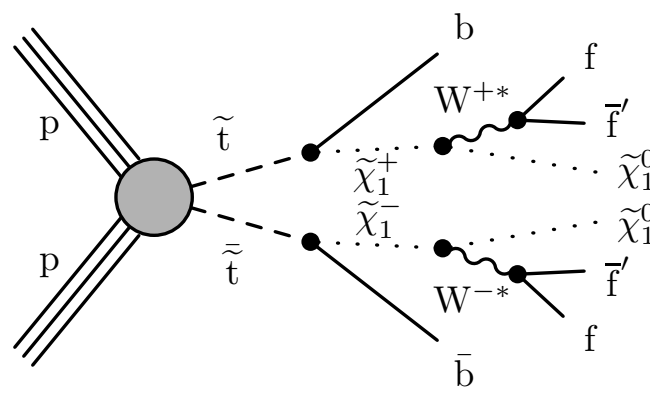
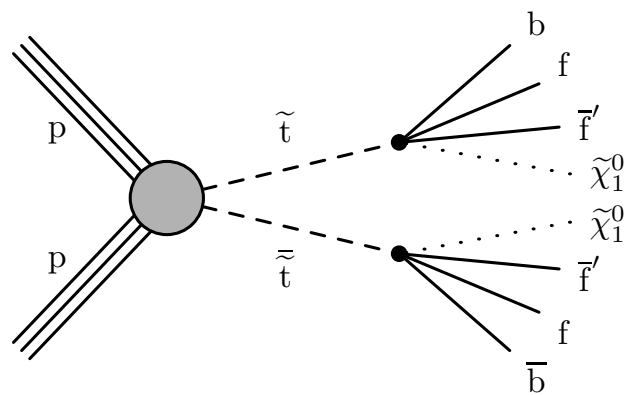
# BACKUP

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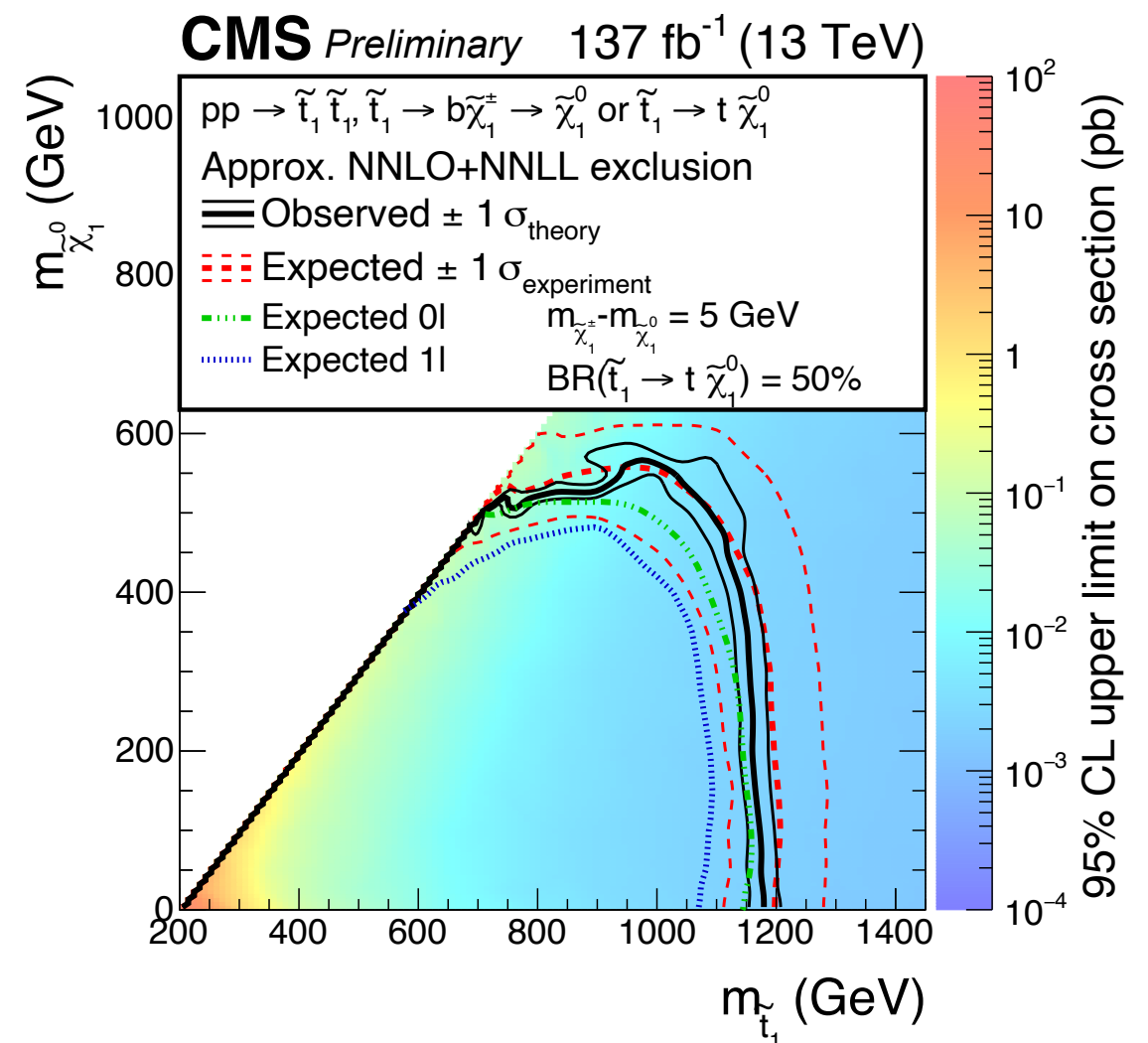
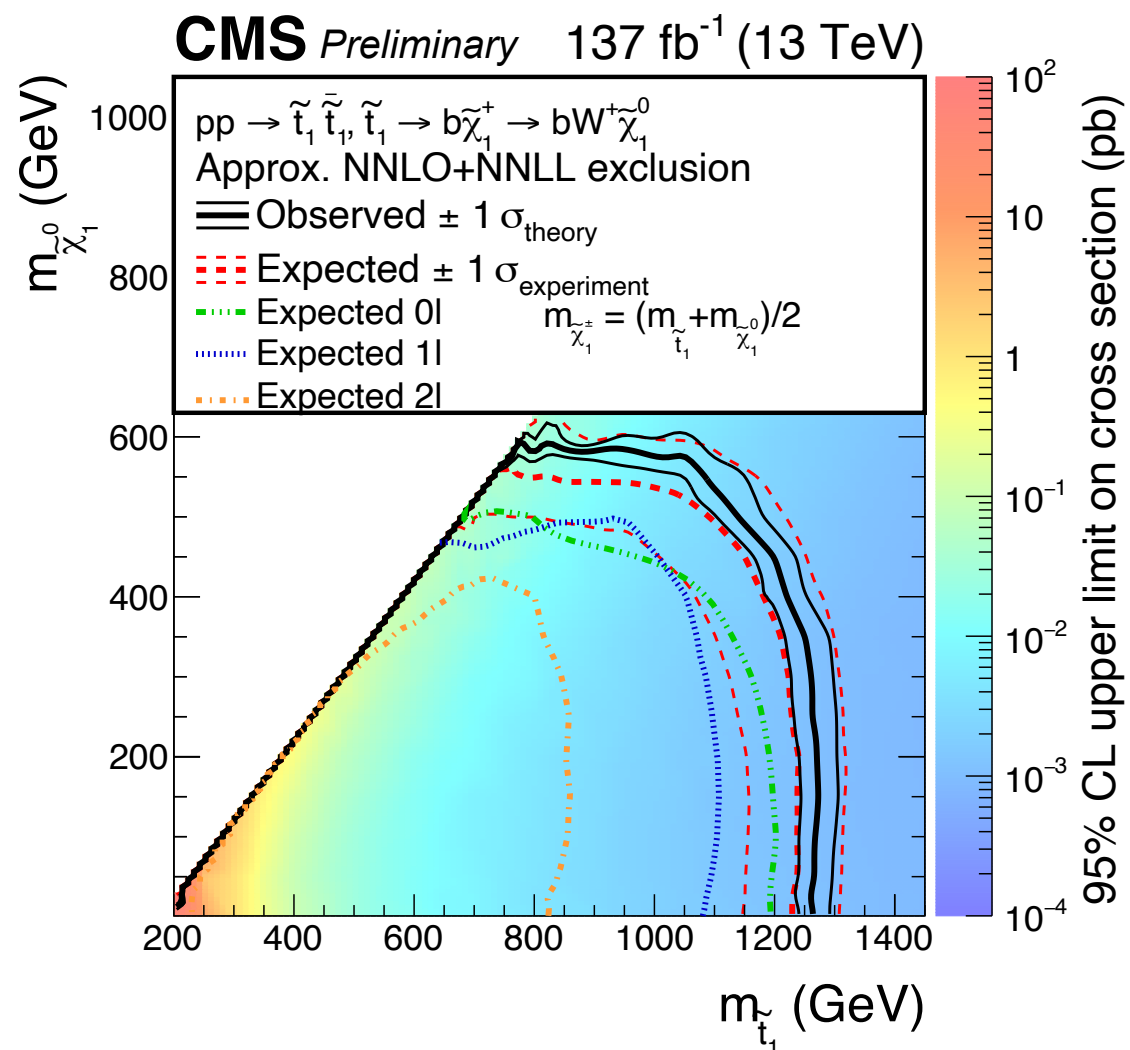
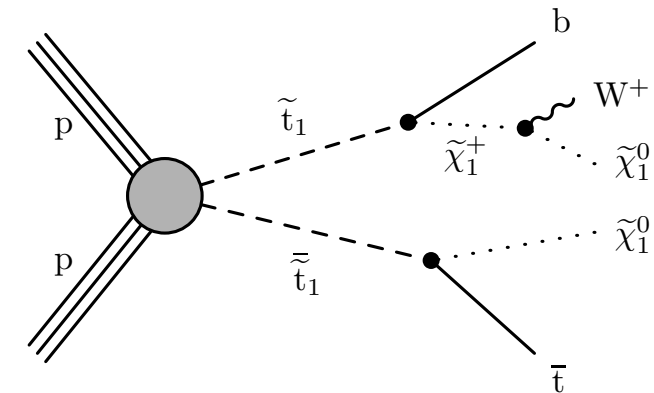
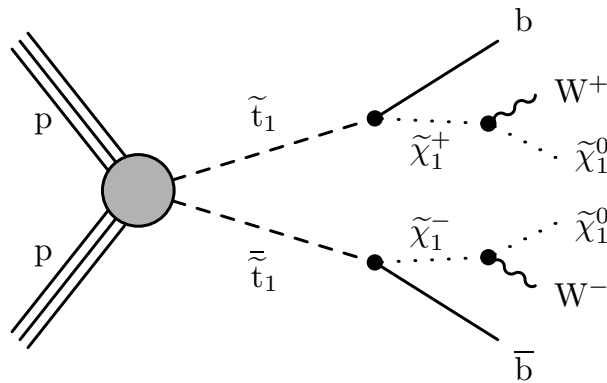


# Hadronic stop

Signal models with  $\Delta m < m_W$ : Decays of top squarks via off-shell top quarks or W bosons

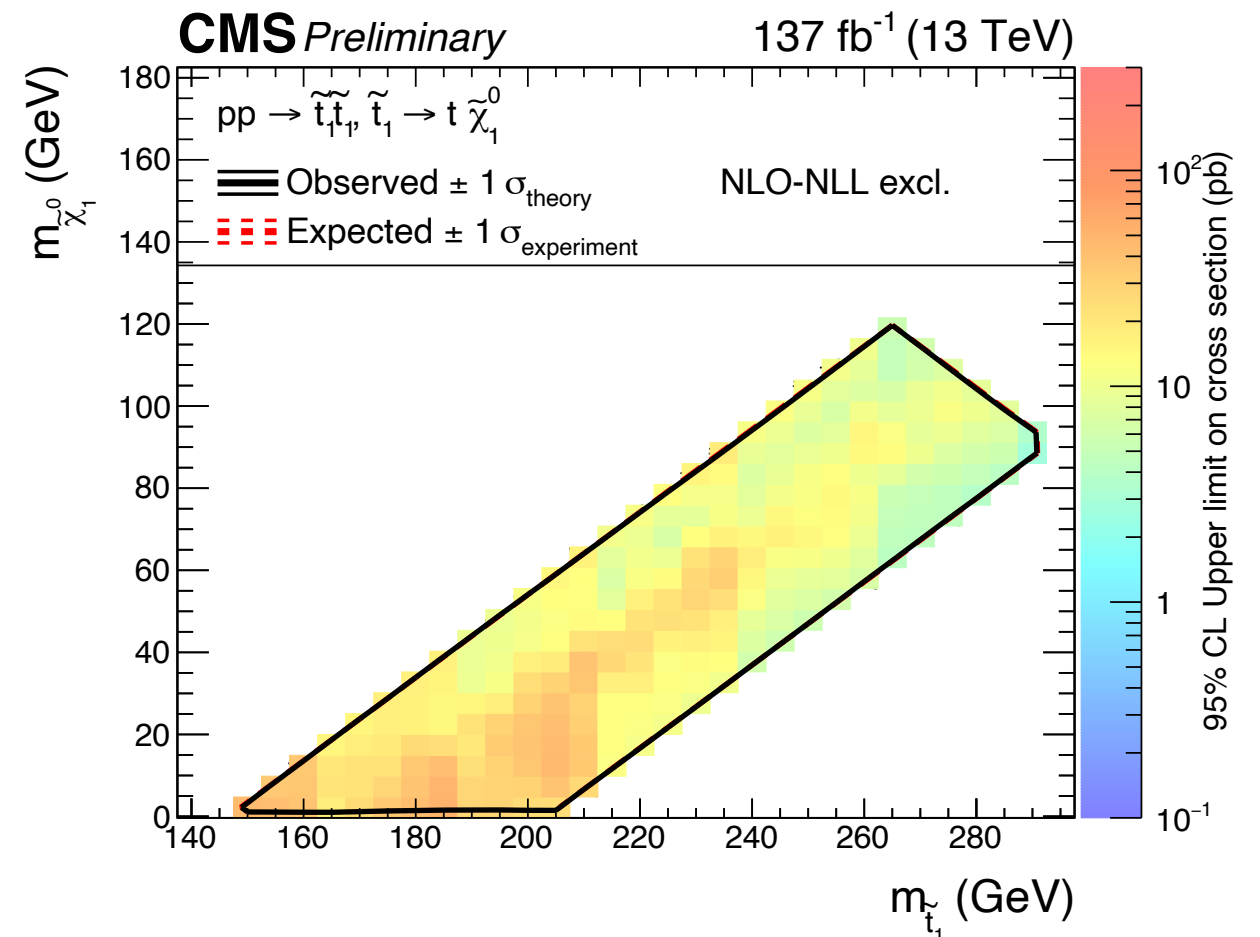
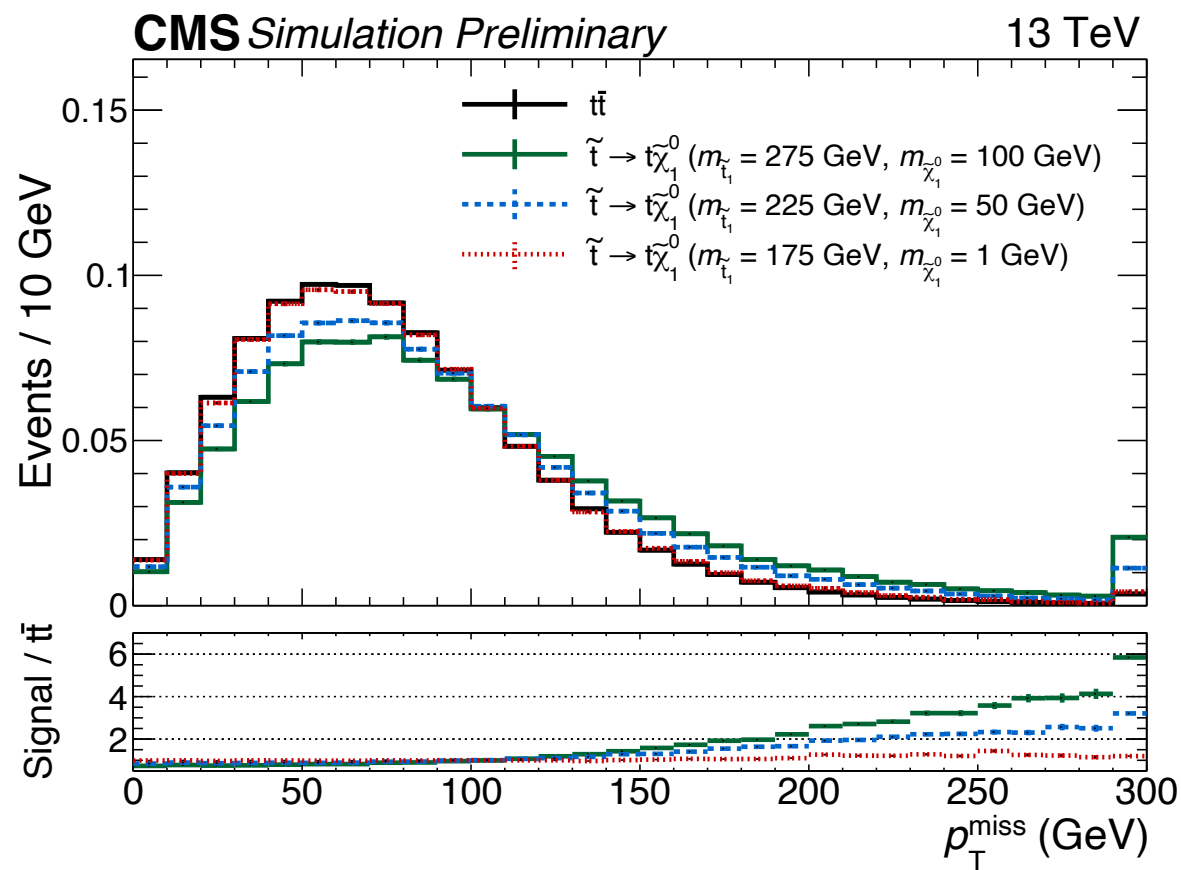


# Top squark combination

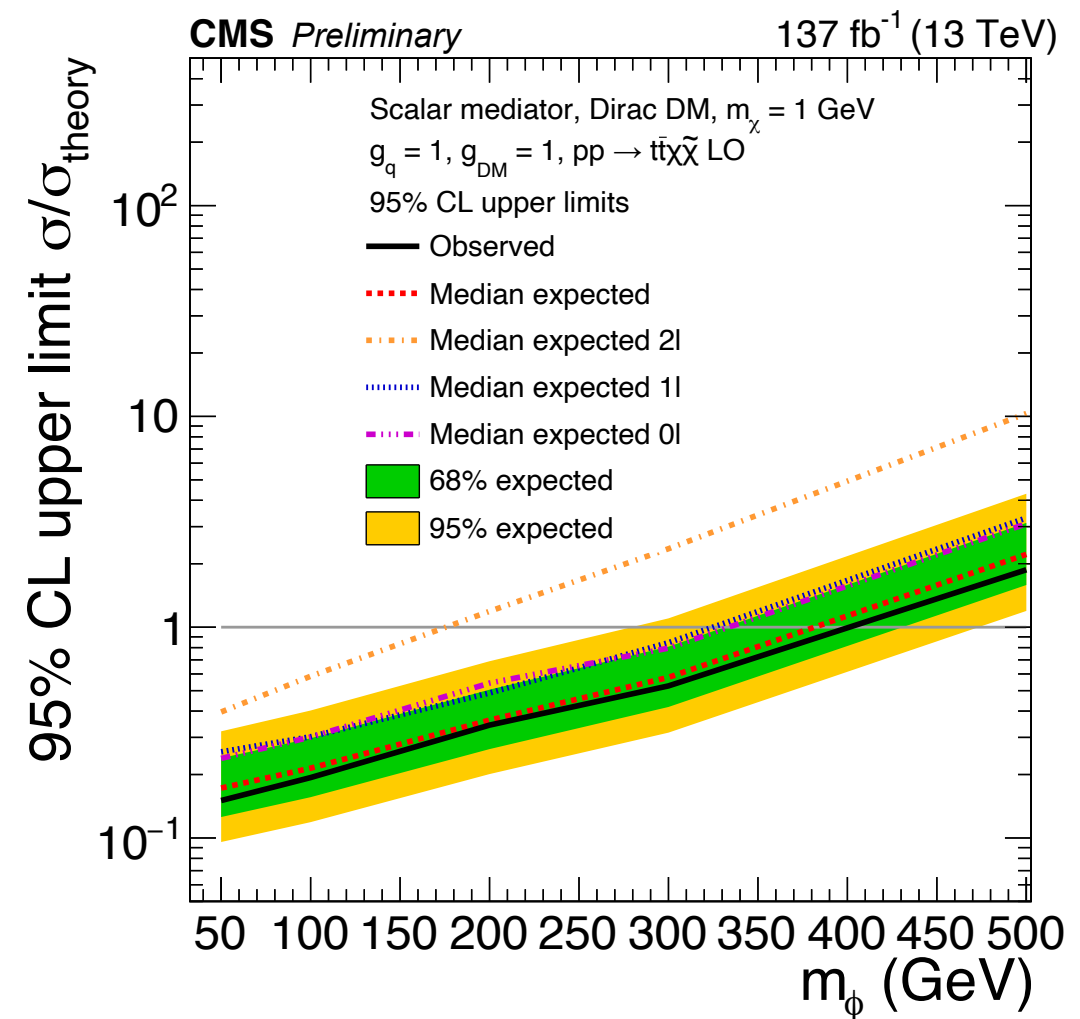
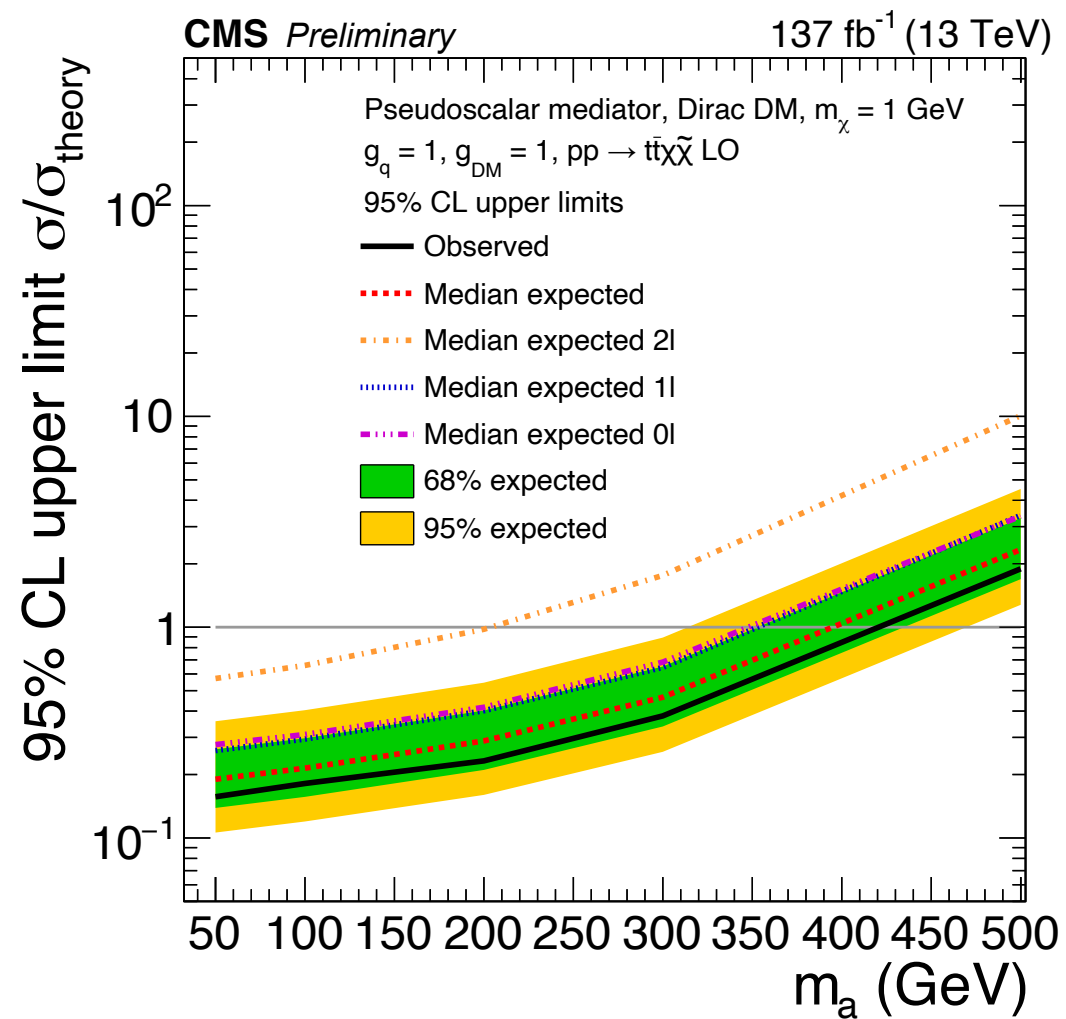
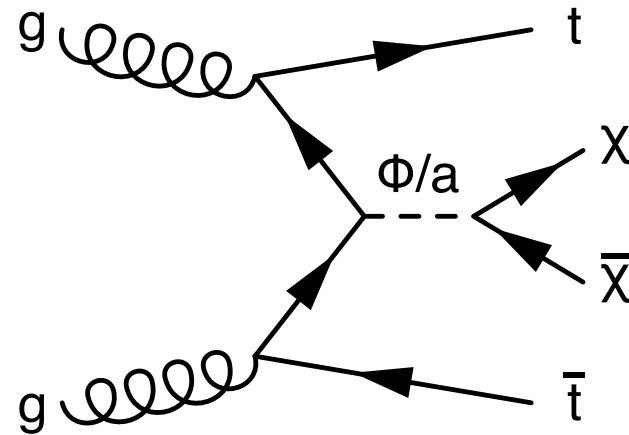


# Top squark combination

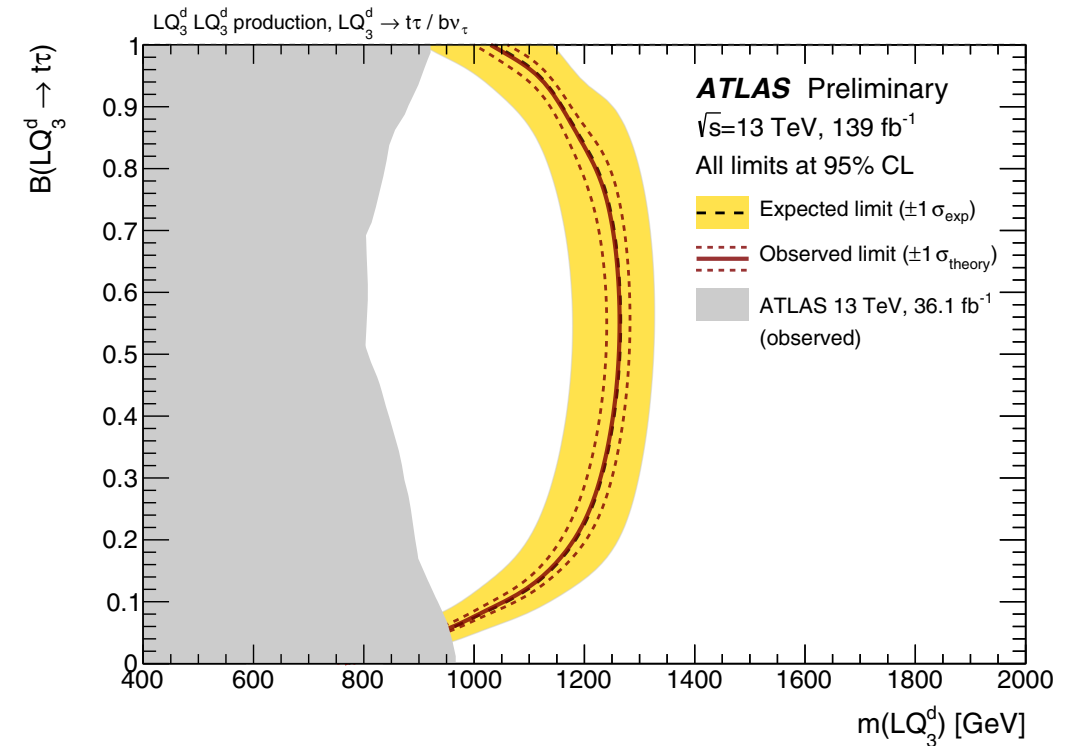
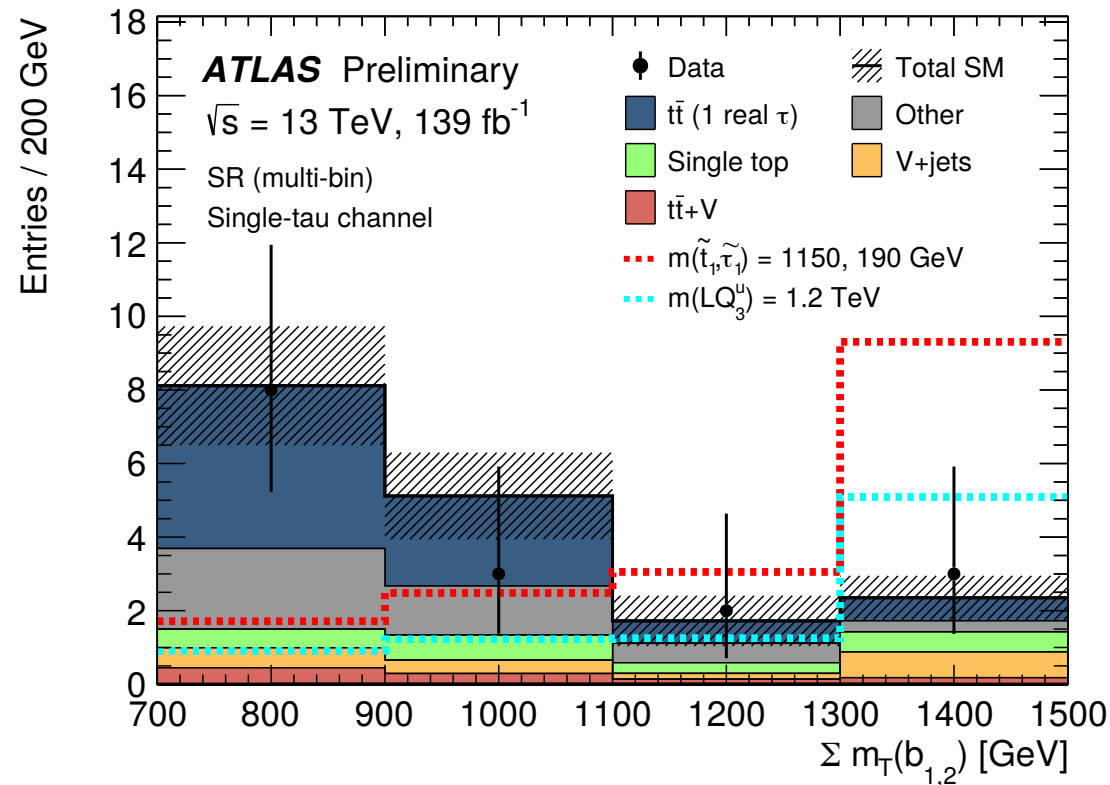
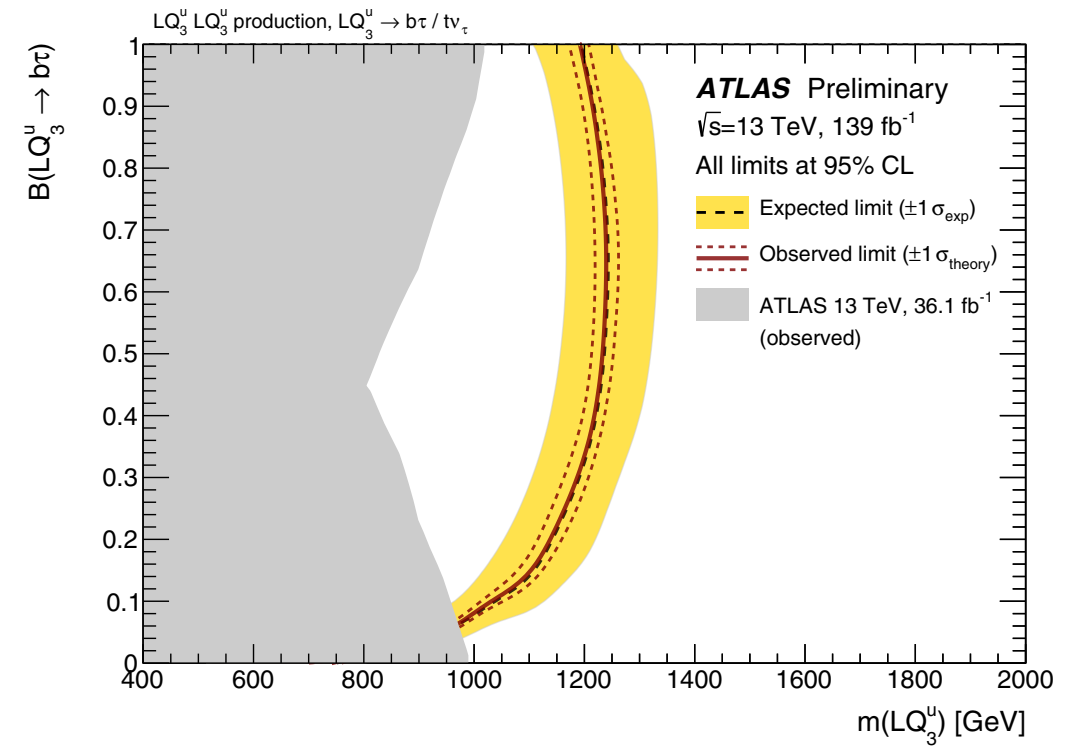
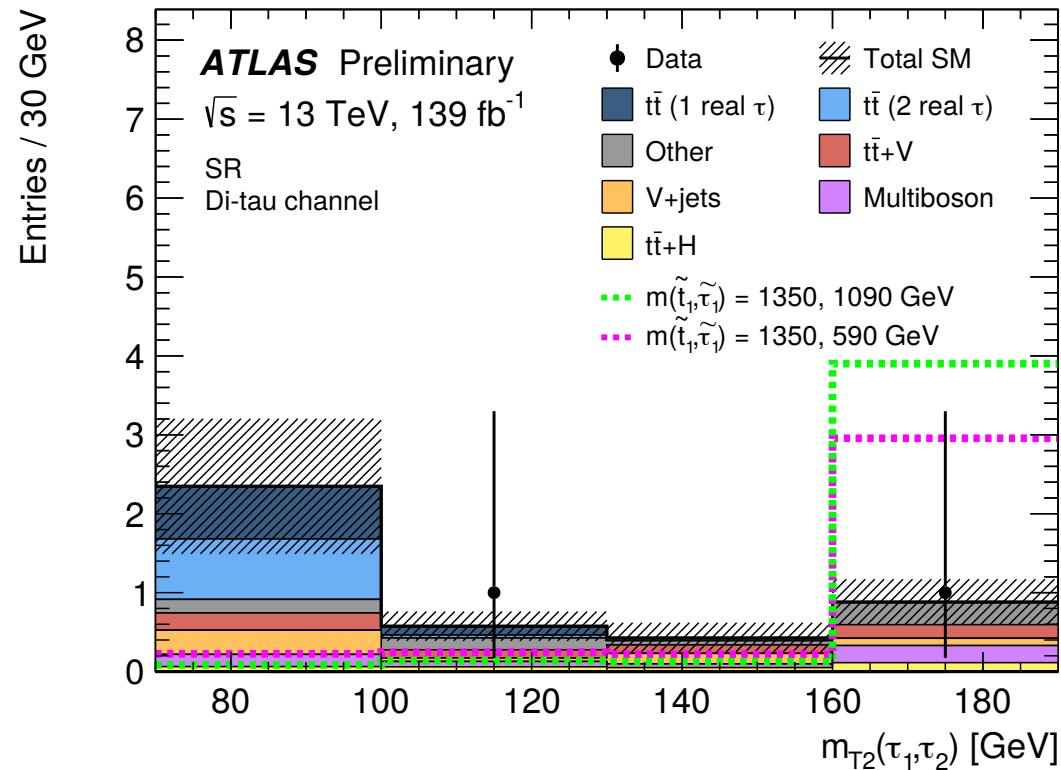
## Top corridor analysis



# Top squark combination

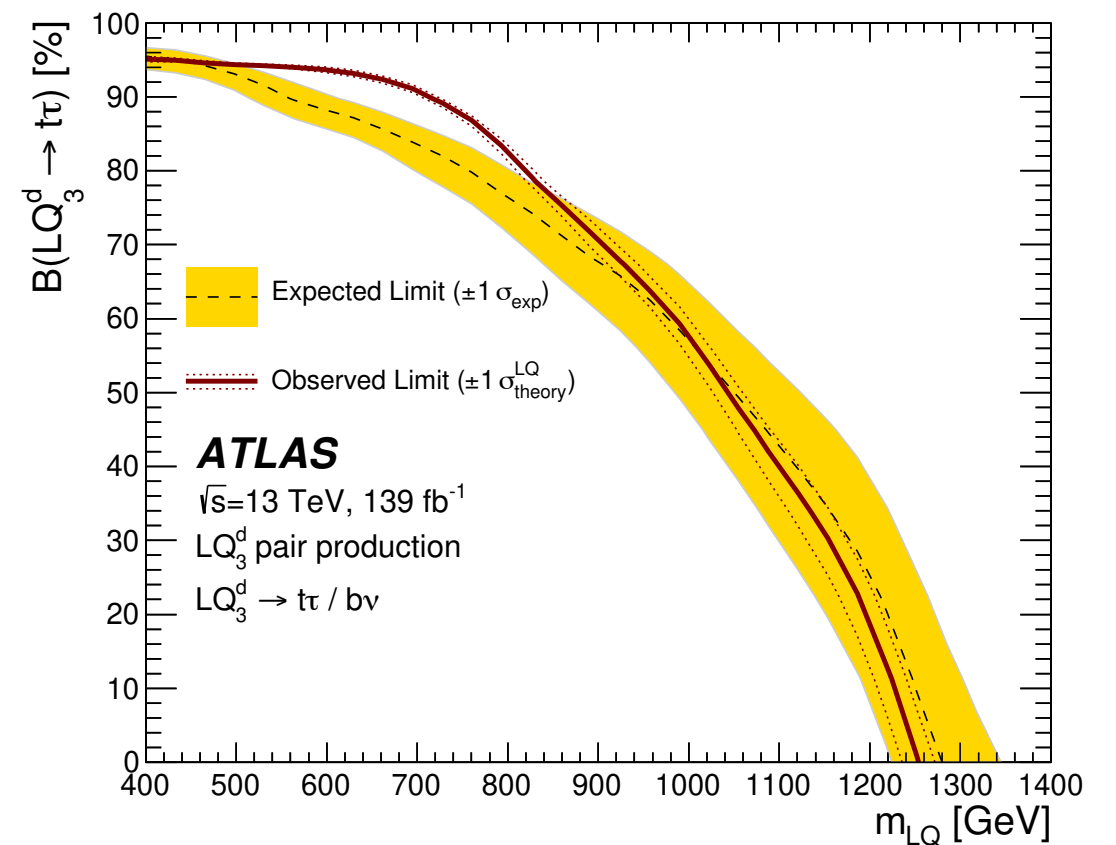
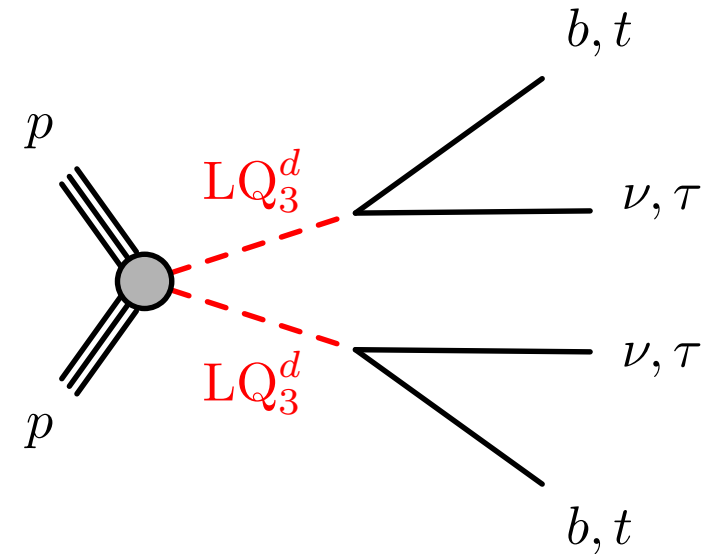
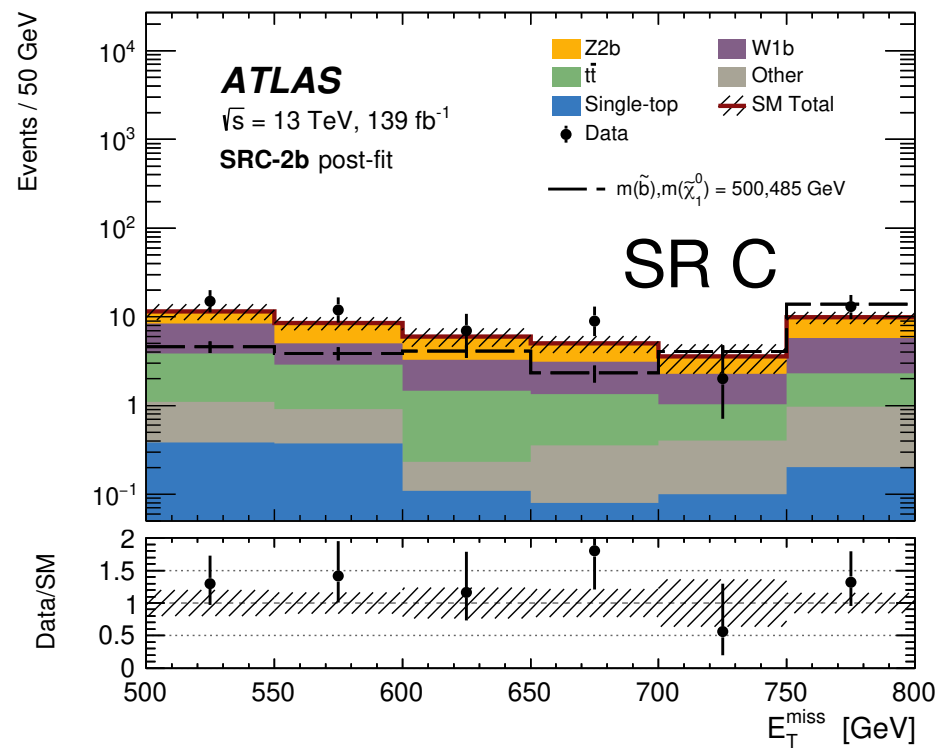
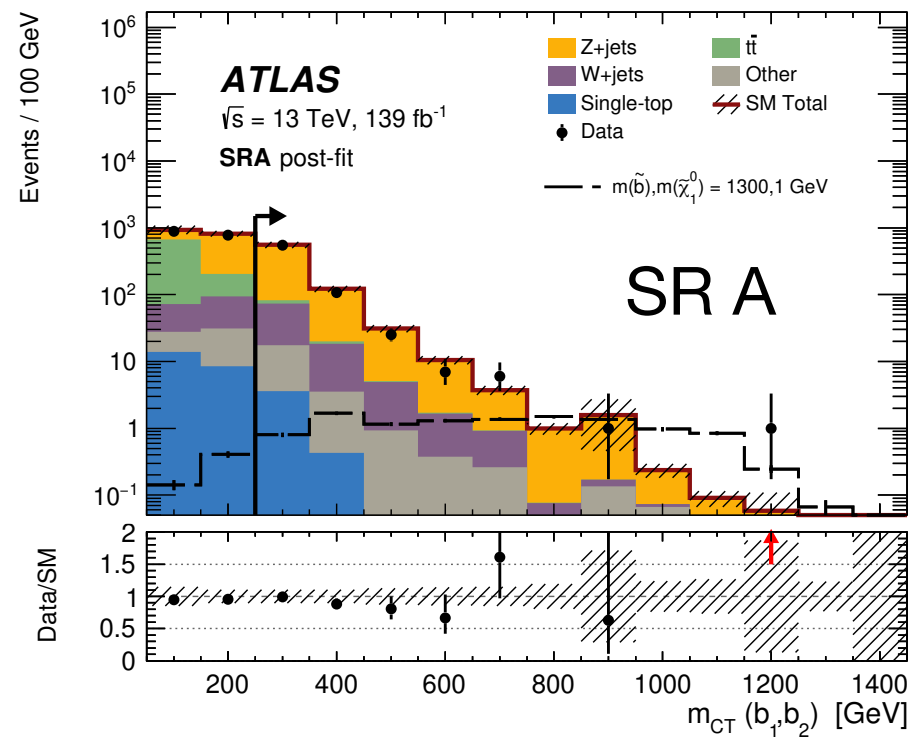


# Stops with taus

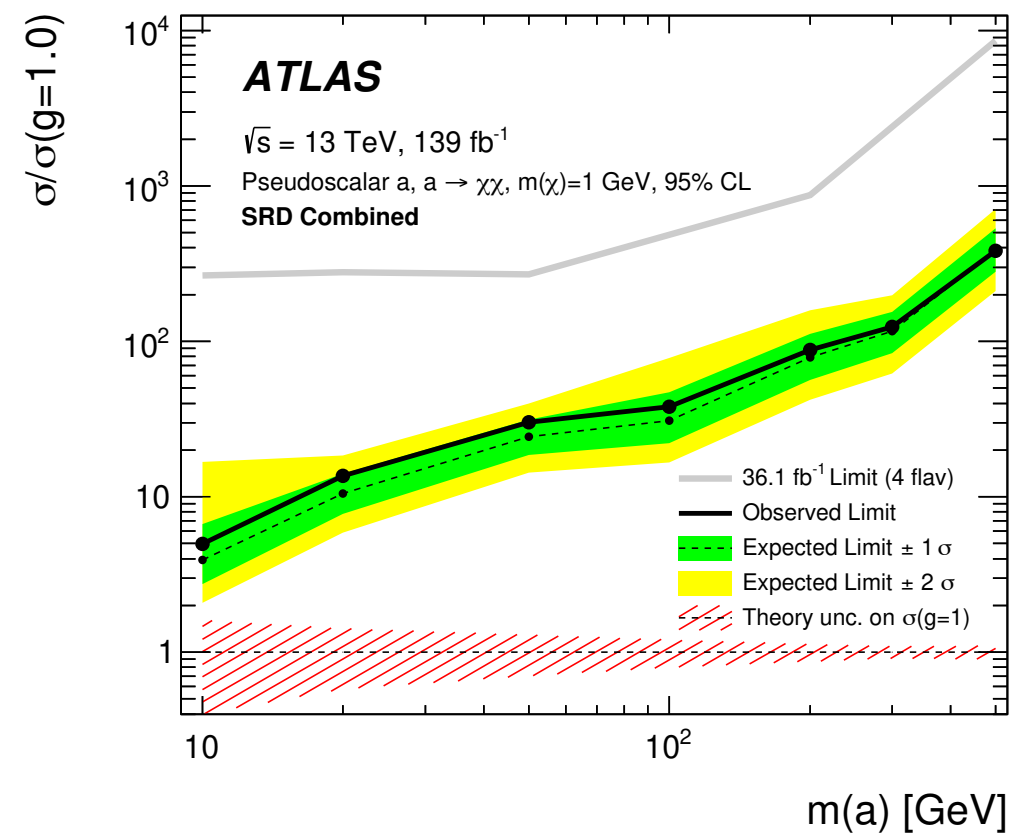
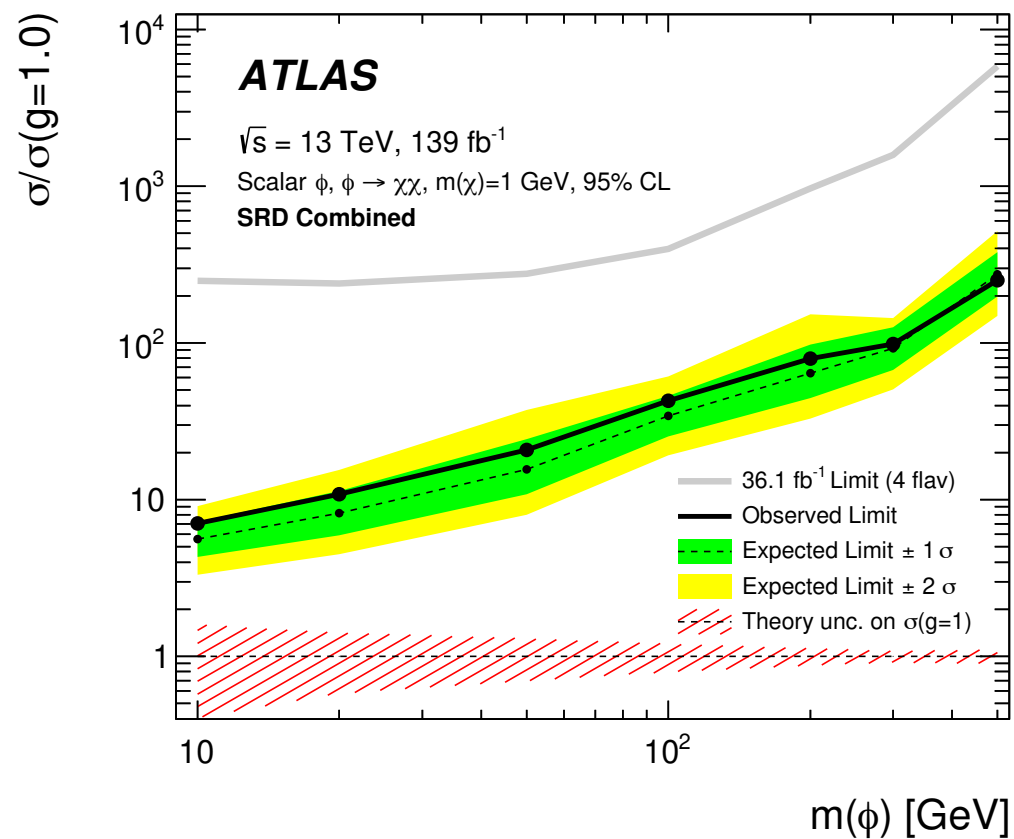
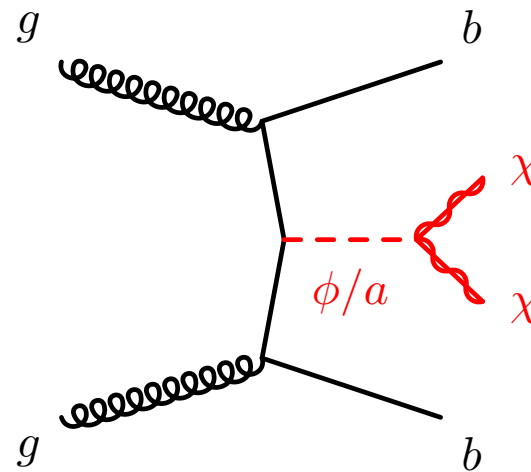




# Direct sbottom production

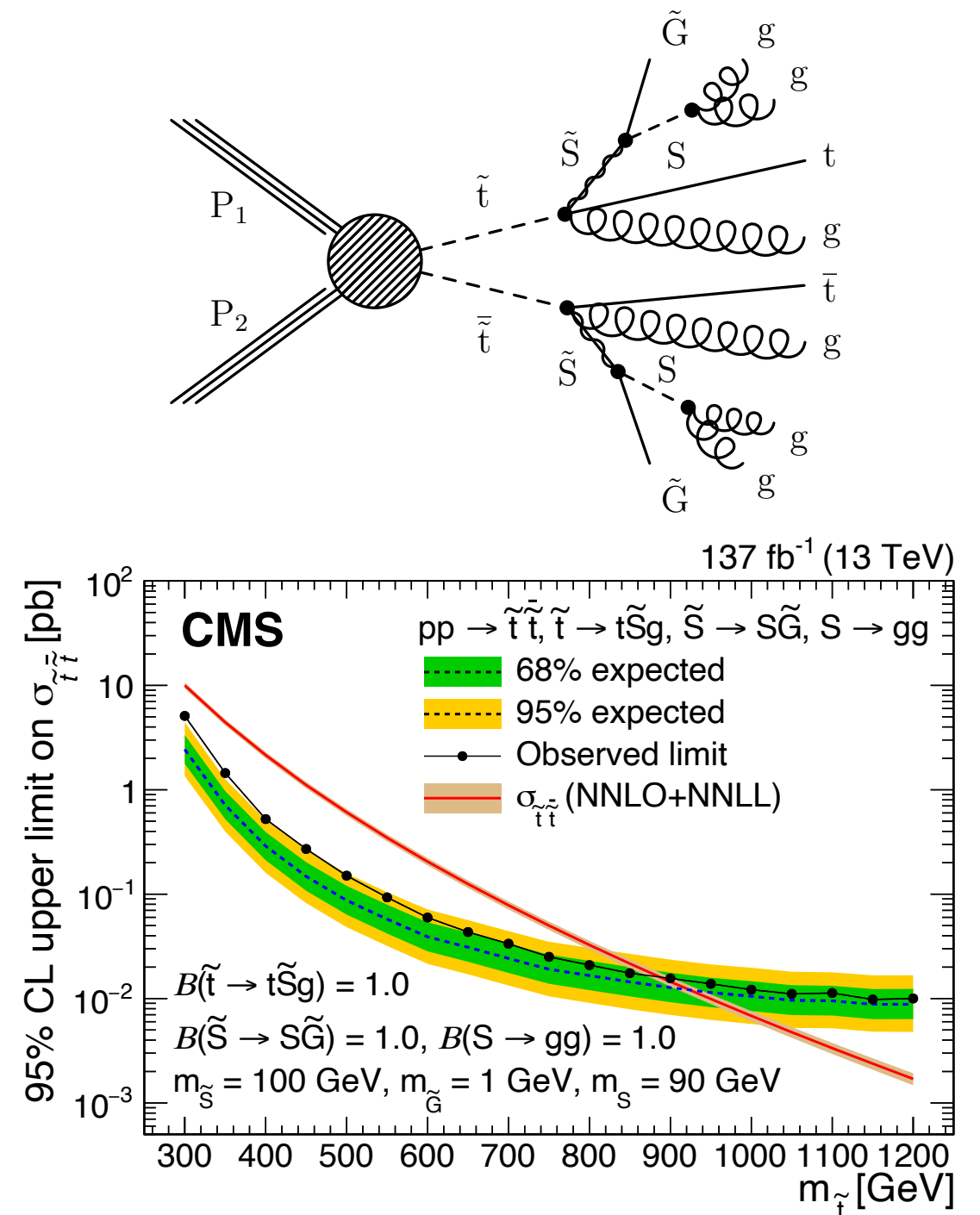
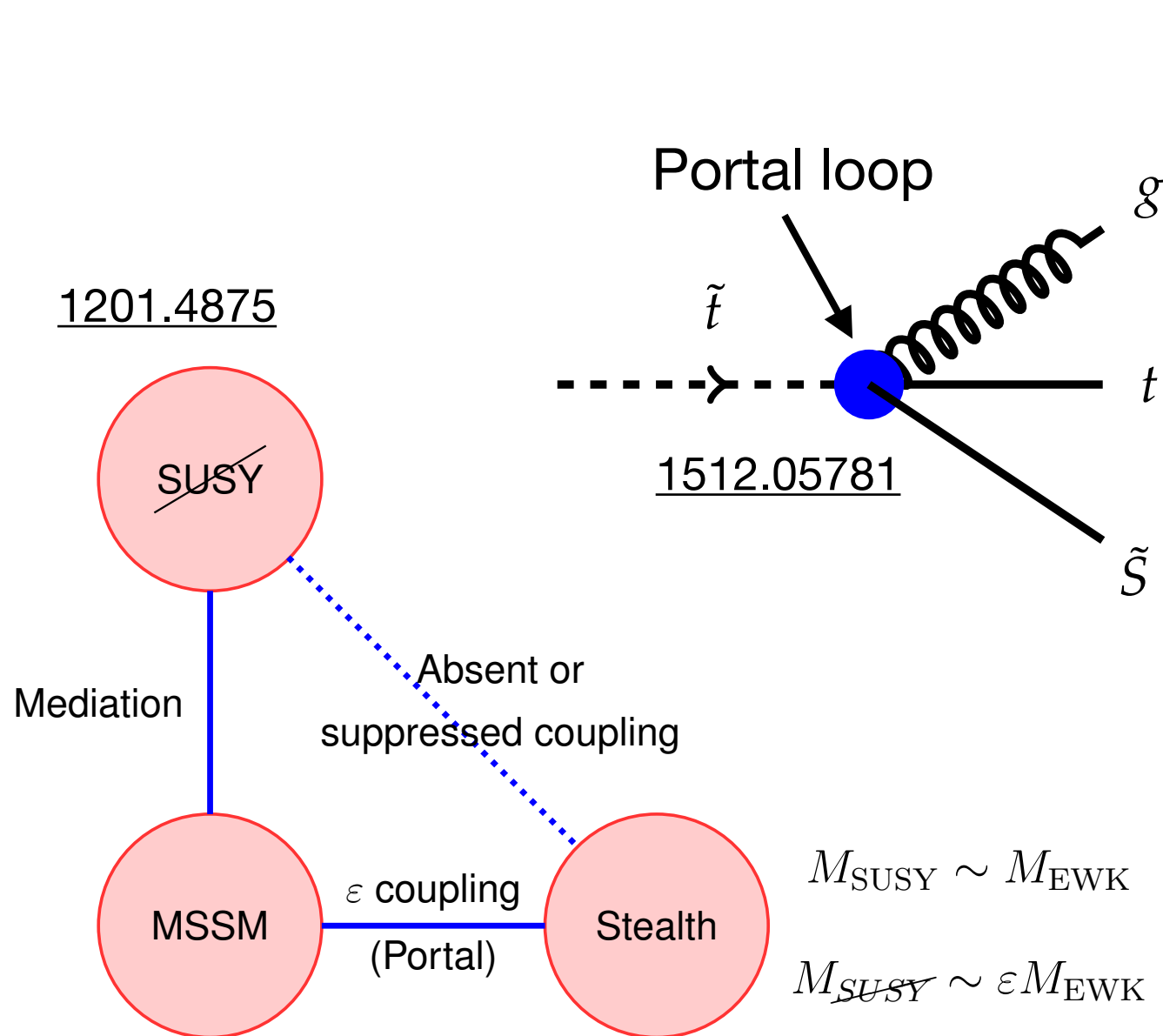


# Direct sbottom production



# Stops without $p_T^{\text{miss}}$ signature

R-parity conserving SUSY with Stealth sector, coupled to MSSM via portal



# HL-LHC

- Constraints from Run 2 are already way beyond the expectations of stops below 1 TeV
- Current HL-LHC projections: Potential reach for 5 $\sigma$  discovery already excluded...

