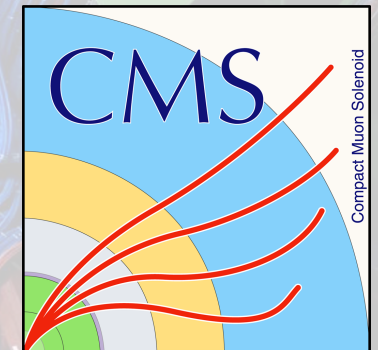# Searches for third generation SUSY particles with the CMS experiment

Giulia Collura, UCSB
on behalf of the CMS collaboration

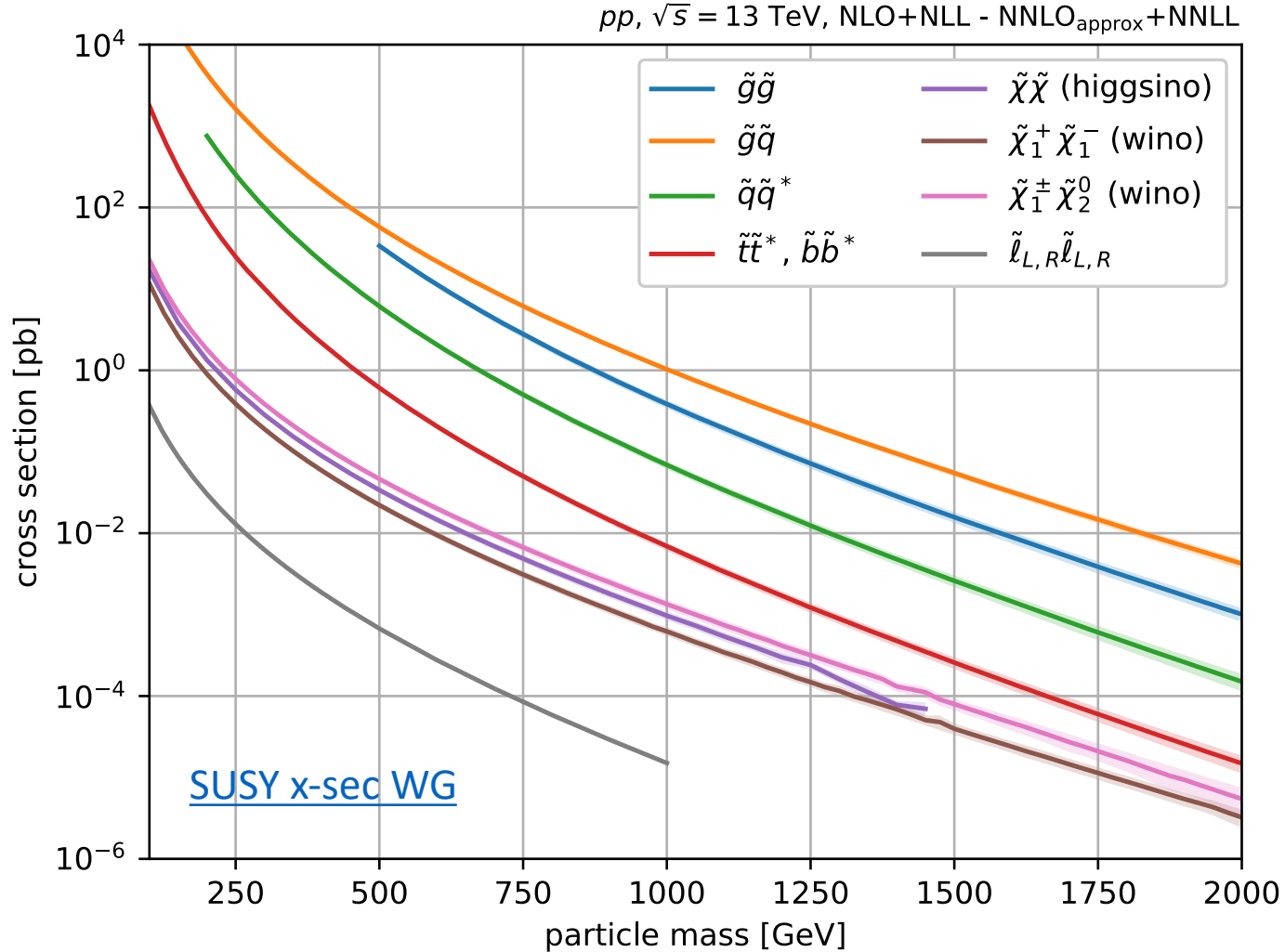**EPS-HEP2021 July 26th 2021**

UC **SANTA BARBARA**

Motivation

In this talk:
Searches for stop pair production
Searches for stau pair production

pp, $\sqrt{s}$ = 13 TeV, NLO+NLL - NNLO$_{approx}$+NNLL

Legend:
- $\tilde{g}\tilde{g}$
- $\tilde{g}\tilde{q}$
- $\tilde{q}\tilde{q}^*$
- $\tilde{t}\tilde{t}^*$, $\tilde{b}\tilde{b}^*$
- $\tilde{\chi}\tilde{\chi}$ (higgsino)
- $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (wino)
- $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ (wino)
- $\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$

SUSY x-sec WG

y-axis: cross section [pb]
x-axis: particle mass [GeV]

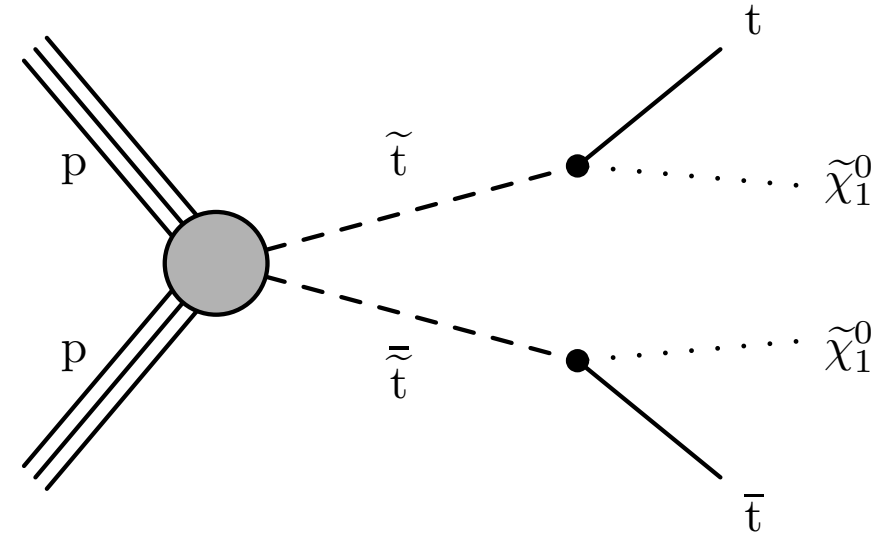Third generation SUSY particles at the TeV scale:

- Provide solution to fine-tuning of Higgs mass

- Stable, massive, and weakly interacting lightest SUSY particle: dark matter candidate

- Decay to t or b quarks, or τ leptons: distinctive experimental signature

- Sizeable cross section for SUSY particles produced through strong interaction

- Stau-neutralino coannihilation in models with $\tilde{\tau}$ as next-to-lightest SUSY particle can explain relic dark matter density
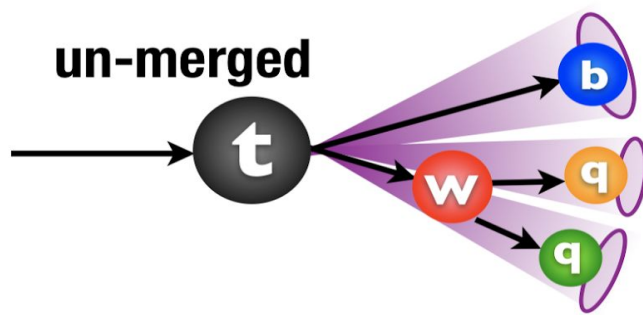
2

Direct top squark production

Top squark pair production final states can have 0, 1 or 2 leptons

- Largest branching fraction is all hadronic final state
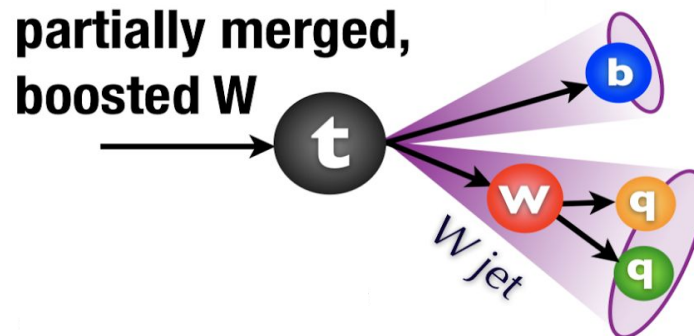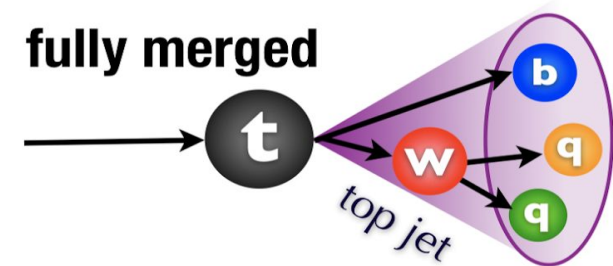- Novel top tagging tools enhance sensitivity

AK4 is anti-k_t R=0.4
AK8 is anti-k_t R=0.8

un-merged

resolved top
from 3 AK4 jets

partially merged, boosted W

merged W in
AK8 jet

fully merged

merged top in
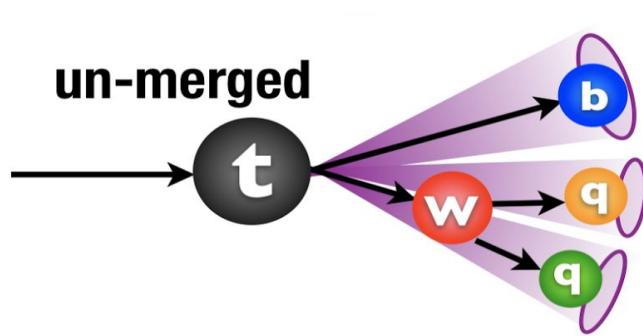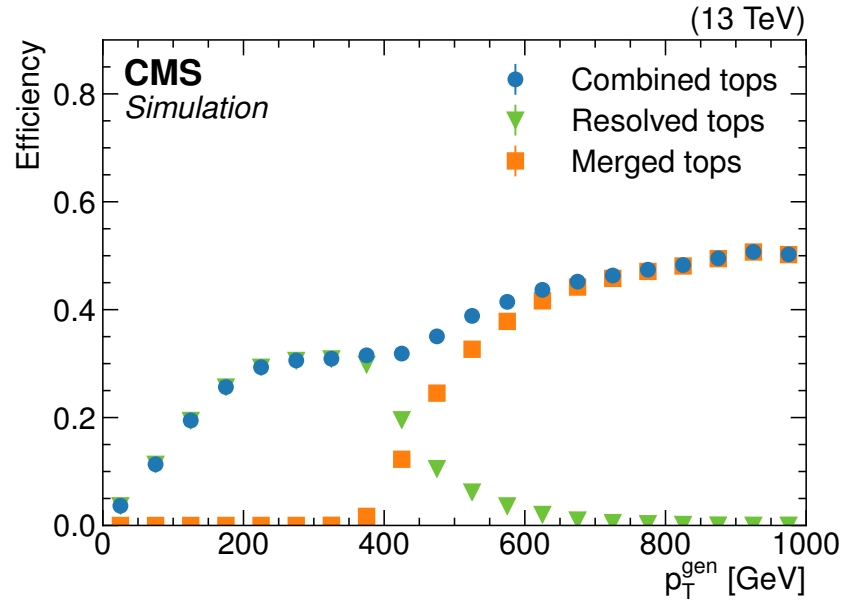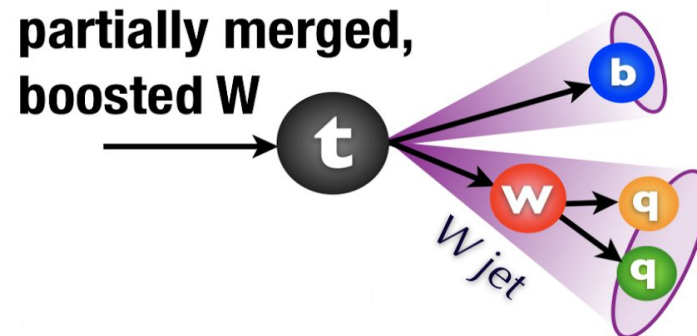AK8 jet

3

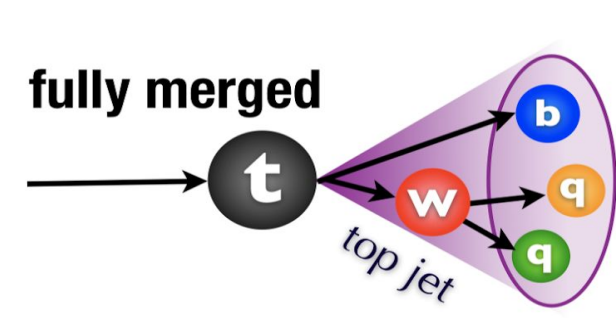# All hadronic top-tagging

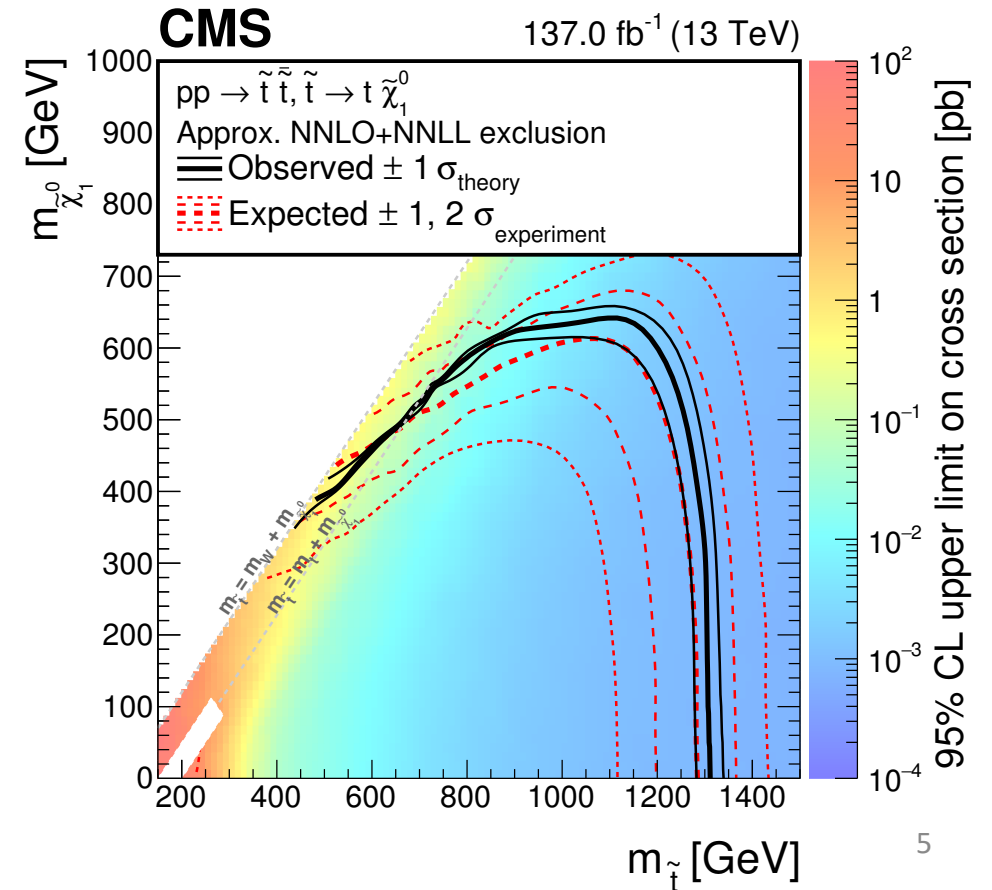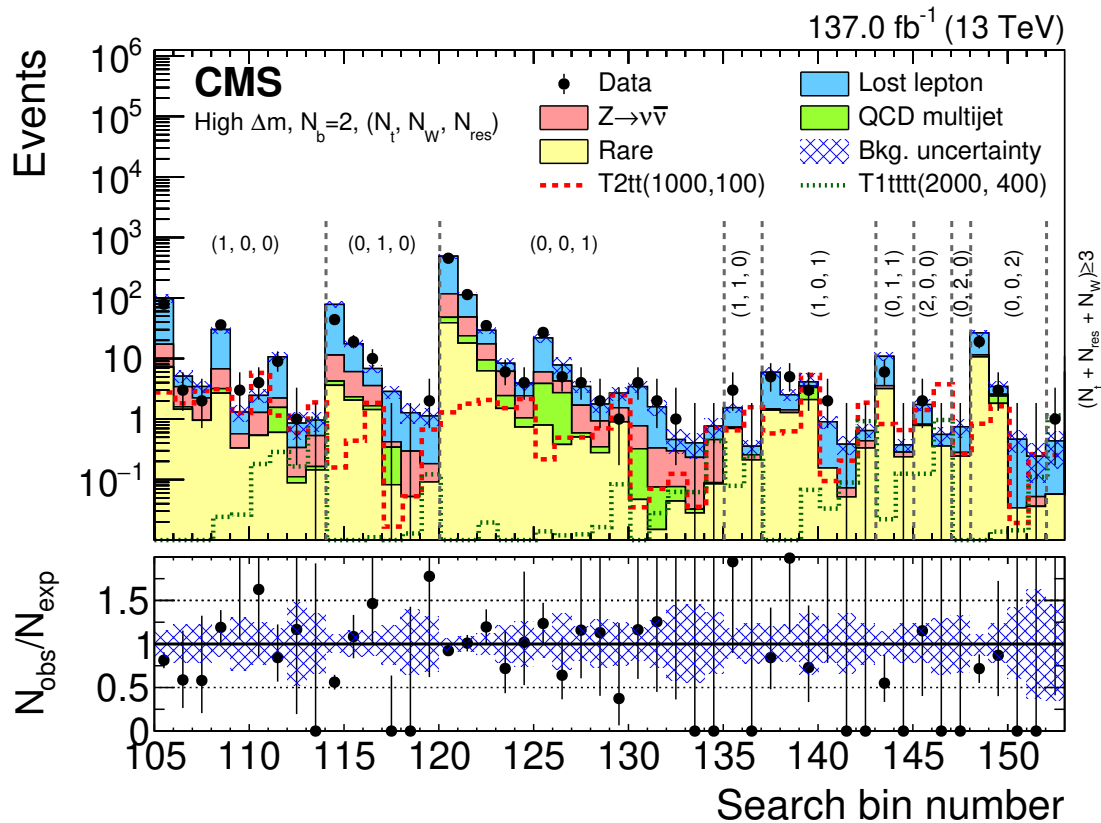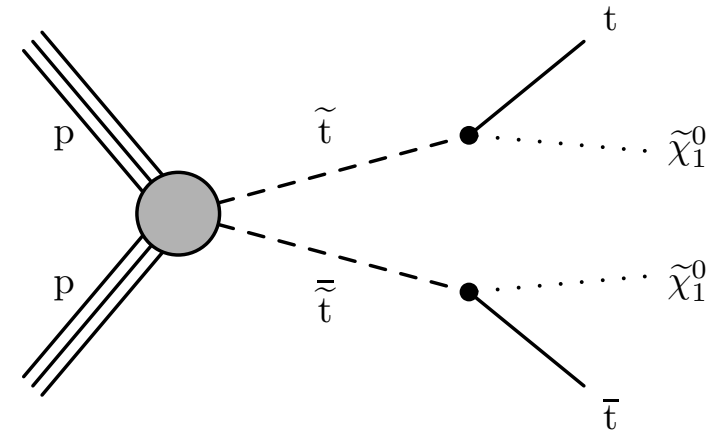resolved top
from 3 AK4 jets

merged W in
AK8 jet

merged top in
AK8 jet

Direct Top Squark Production

Analysis sensitive to many signal models (more results in the backup)

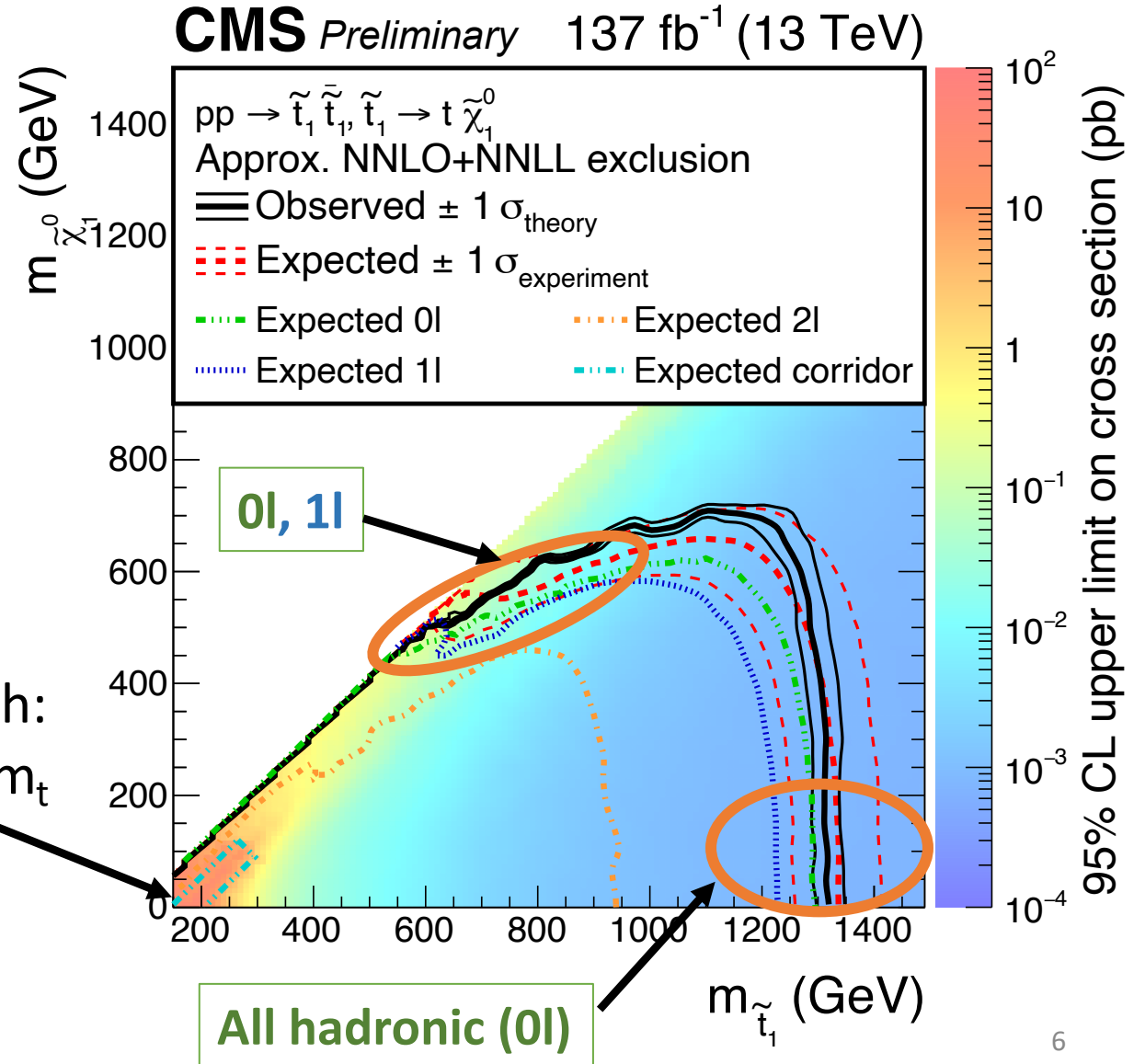Excluded top squark masses up to 1.3 TeV

Top Squark Combination

Combination of searches in 0, 1, and 2 lepton final state

- Excludes top squarks up to 1350 GeV for certain models

- Corridor with $\Delta m(\tilde{t}, \widetilde{\chi}_1^0) \simeq m_t$ targeted with dedicated search

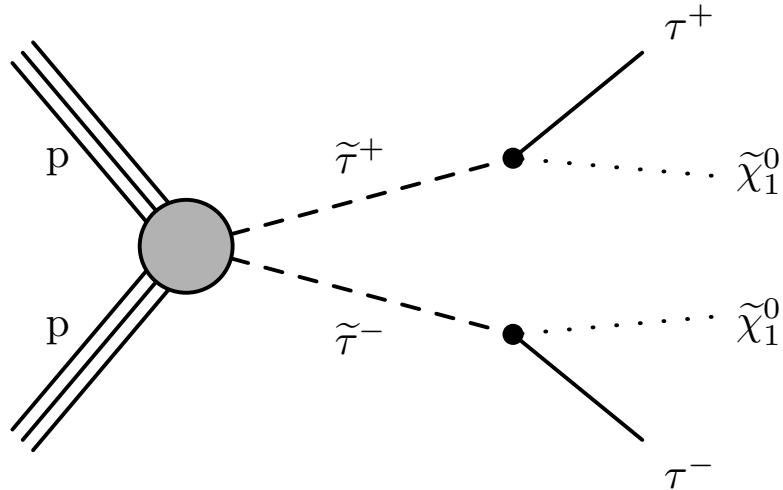Corridor and RPV and stealth stop: Peter's talk at 11:00

Corridor search: $\Delta m(\tilde{t}, \widetilde{\chi}_1^0) \simeq m_t$

CMS *Preliminary*   137 fb^{-1} (13 TeV)

$pp \to \tilde{t}_1 \bar{\tilde{t}}_1, \tilde{t}_1 \to t \widetilde{\chi}_1^0$
Approx. NNLO+NNLL exclusion
Observed ± 1 σ_{theory}
Expected ± 1 $\sigma_{experiment}$
Expected 0l   Expected 2l
Expected 1l   Expected corridor

$m_{\widetilde{\chi}_1^0}$ (GeV)

$m_{\tilde{t}_1}$ (GeV)

95% CL upper limit on cross section (pb)

0l, 1l

All hadronic (0l)

6

All-hadronic Tau Slepton Search
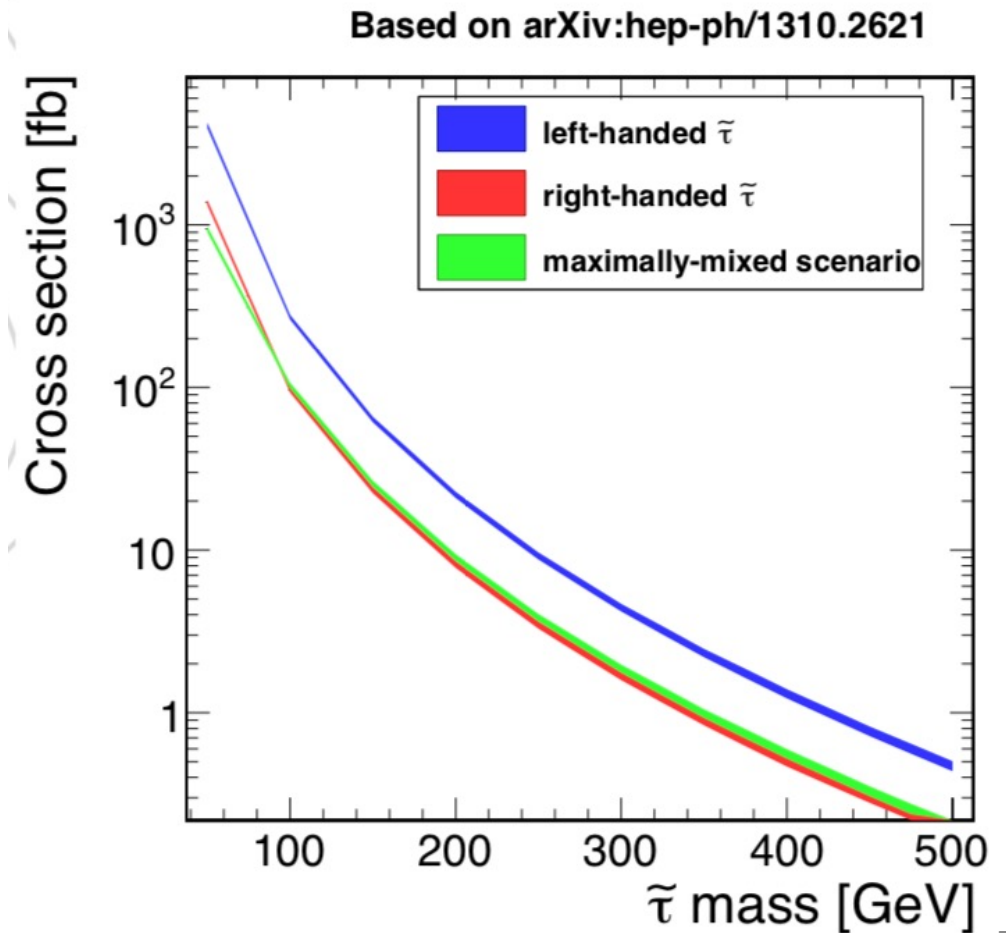
New for full Run II

CMS-SUS-PAS-21-001

Signal models:
Prompt staus: left handed (LH), right handed (RH),
and degenerate production (LH+RH),
Long-lived staus $\rightarrow$ displaced taus:
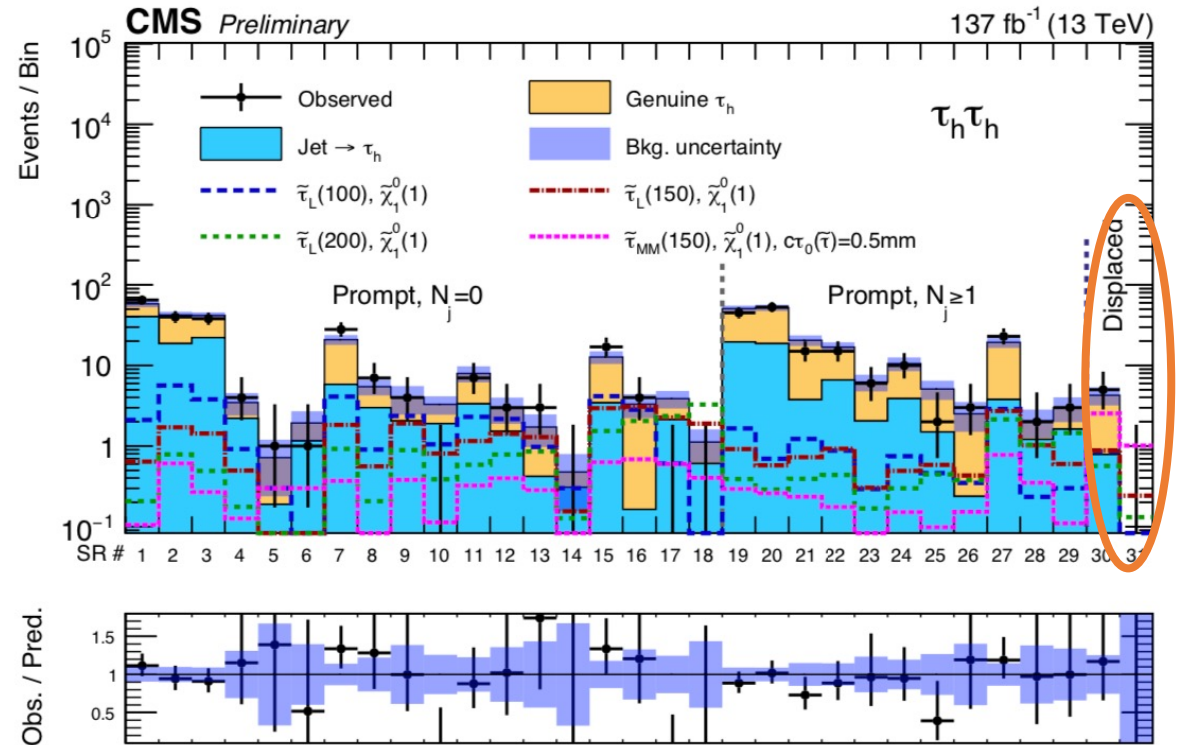Sensitive to GMSB SUSY scenarios

Tau ID based on Deep Neural Network
Data-driven methods for estimating backgrounds
from genuine taus and fakes from quark/gluon jets

Based on arXiv:hep-ph/1310.2621

- left-handed $\tilde{\tau}$
- right-handed $\tilde{\tau}$
- maximally-mixed scenario

Cross section [fb]

$\tilde{\tau}$ mass [GeV]

All-hadronic Tau Slepton Search

Embedded sample: models the di-tau background more precisely than MC

Dedicated search regions for displaced taus

$Z \rightarrow \mu\mu$ Selection

$Z \rightarrow \tau\tau$ Simulation

Simulate τ leptons with same kinematic properties as muons.

$Z \rightarrow \mu\mu$ Cleaning

Remove energy deposits from muons.

$Z \rightarrow \tau\tau$ Hybrid

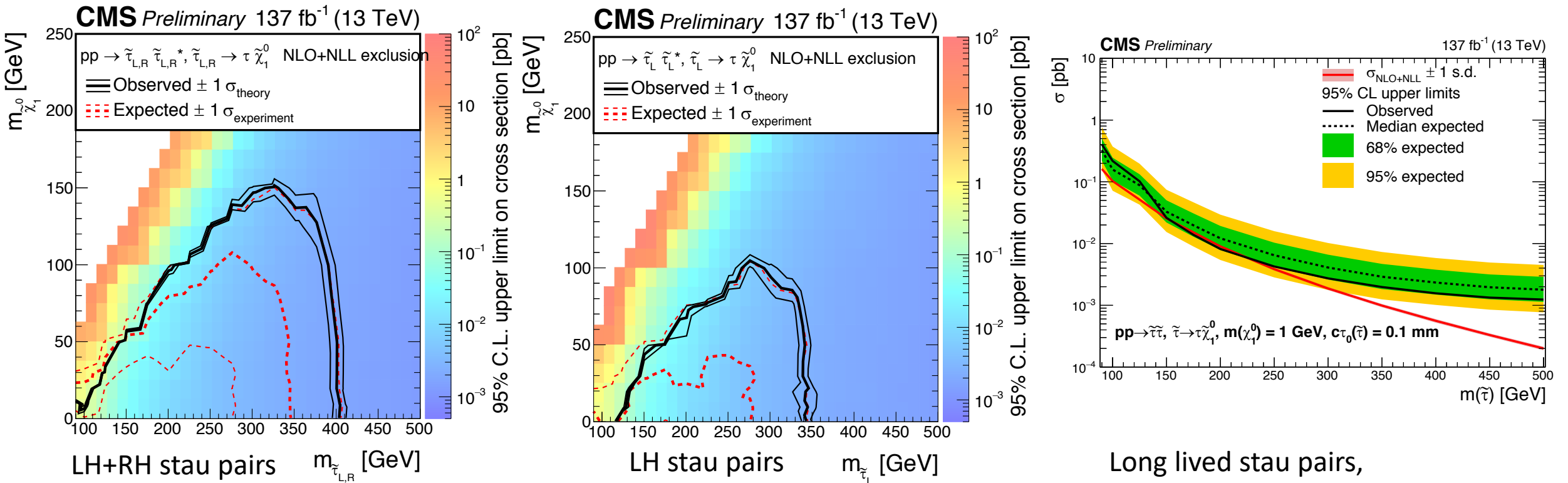Merge simulated and cleaned event.
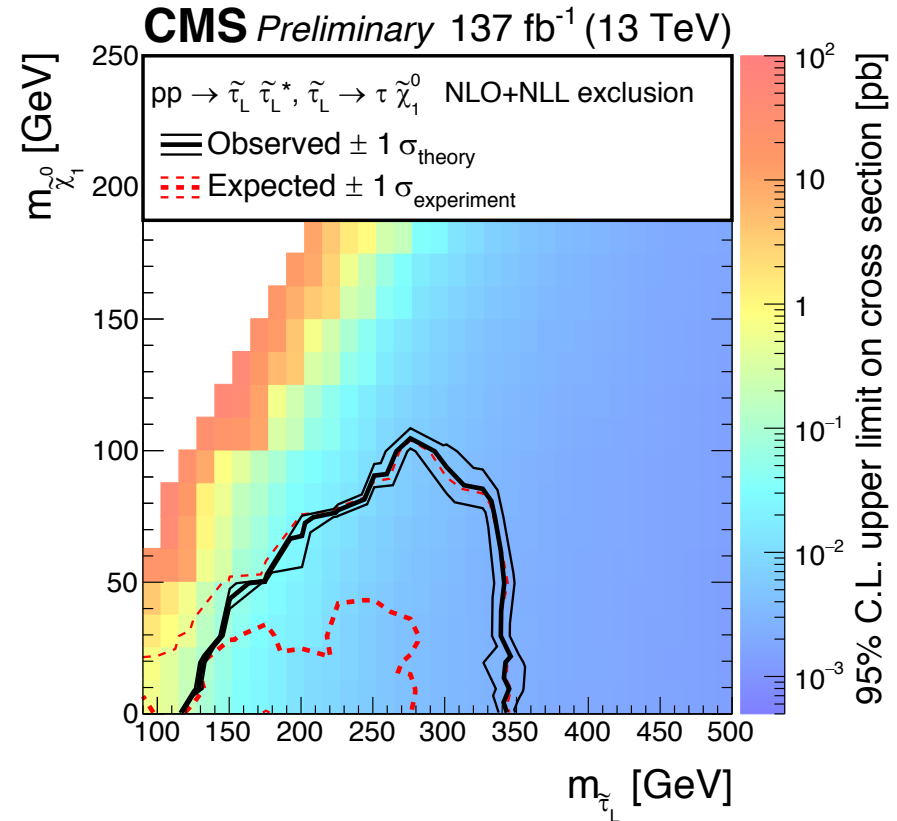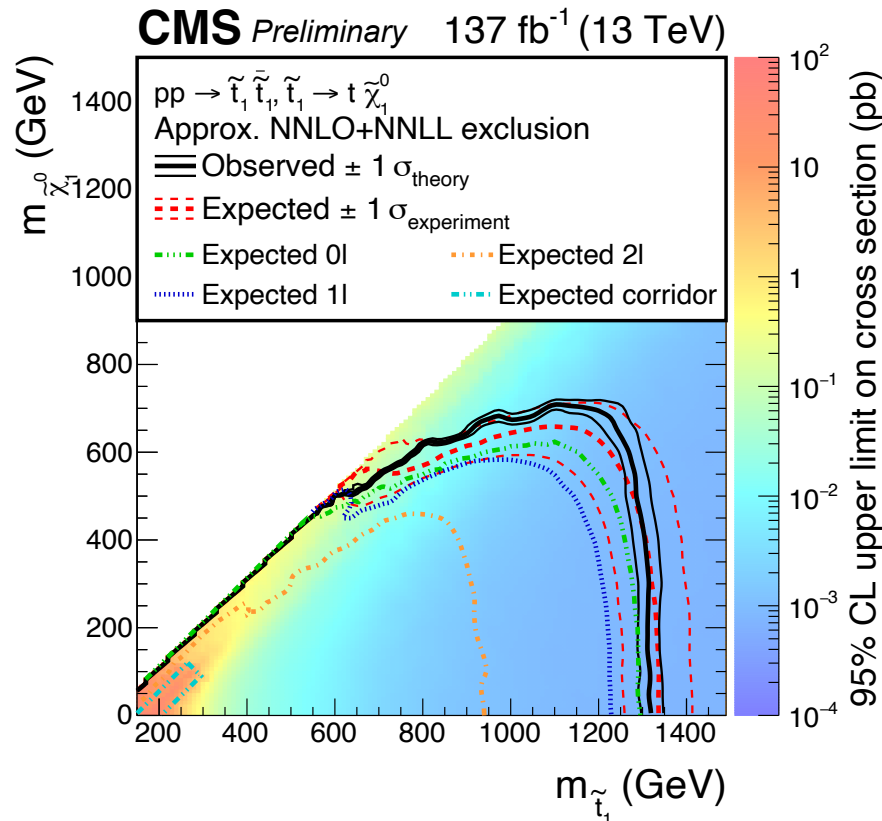
Interpretations

Excluded degenerate stau production up to 400 GeV.

The search also targets long lived staus, which can occur in GMSB models

LH+RH stau pairs

LH stau pairs

Long lived stau pairs,
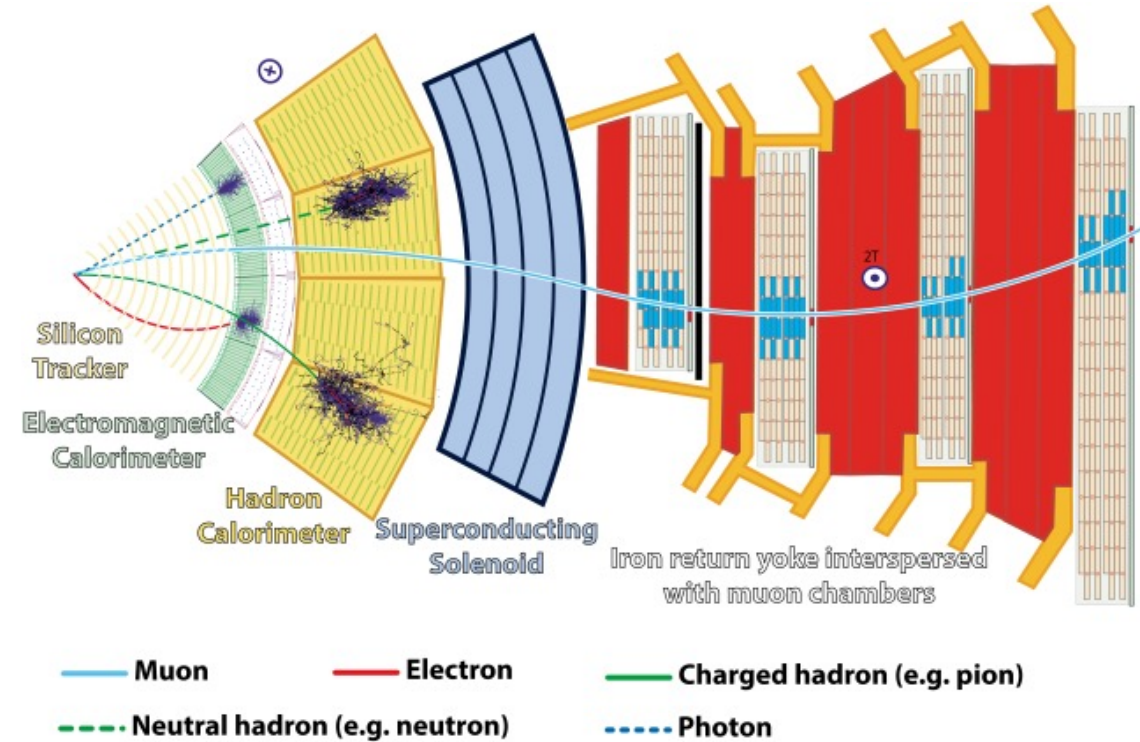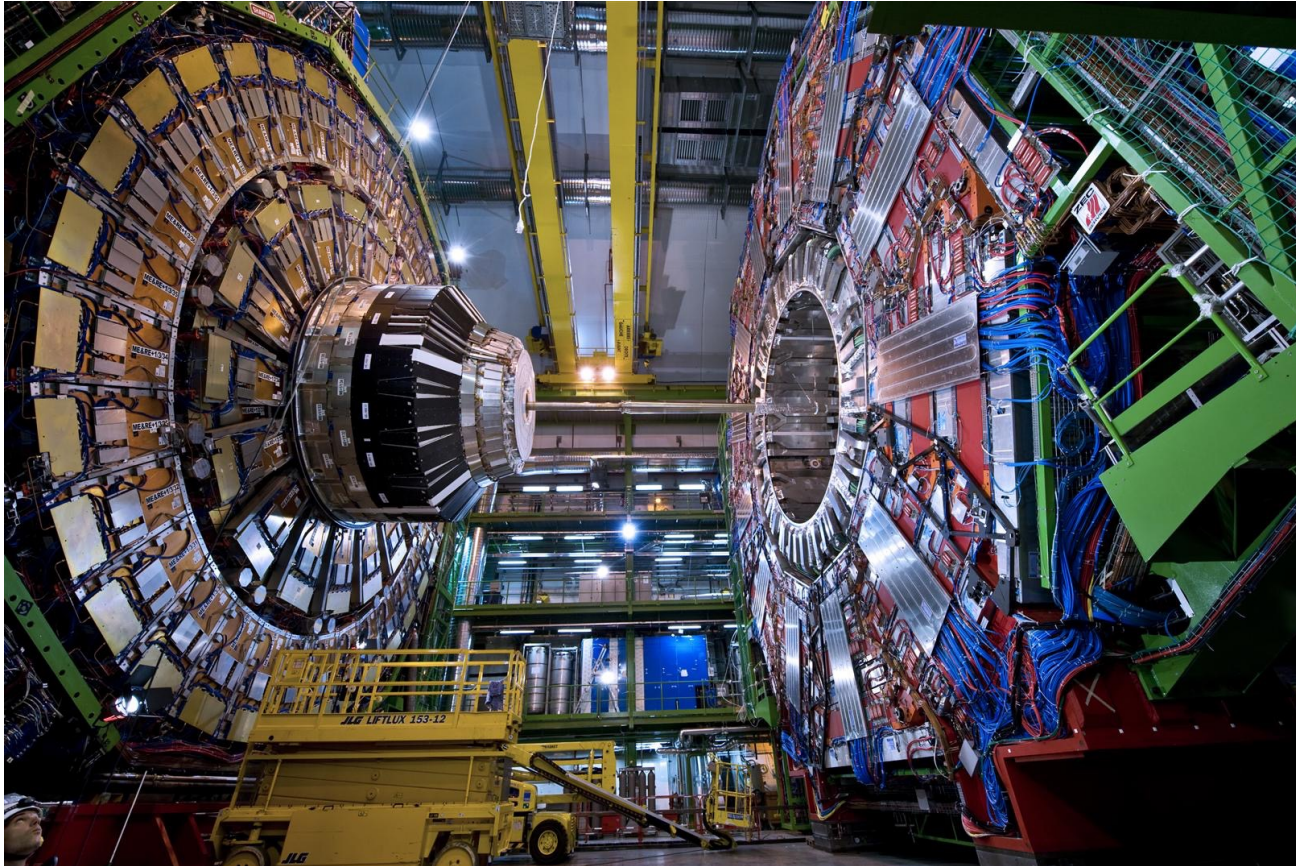Maximally mixed scenario

Summary

- Stops excluded up to 1350 GeV in a wide range of simplified models

- Staus excluded up to 400 GeV in degenerate scenario and 350 GeV in LH scenario

- First result with long lived staus giving rise to displaced hadronic taus

- Completing a comprehensive Run 2 program and more to explore with Run3 data and the HL-LHC
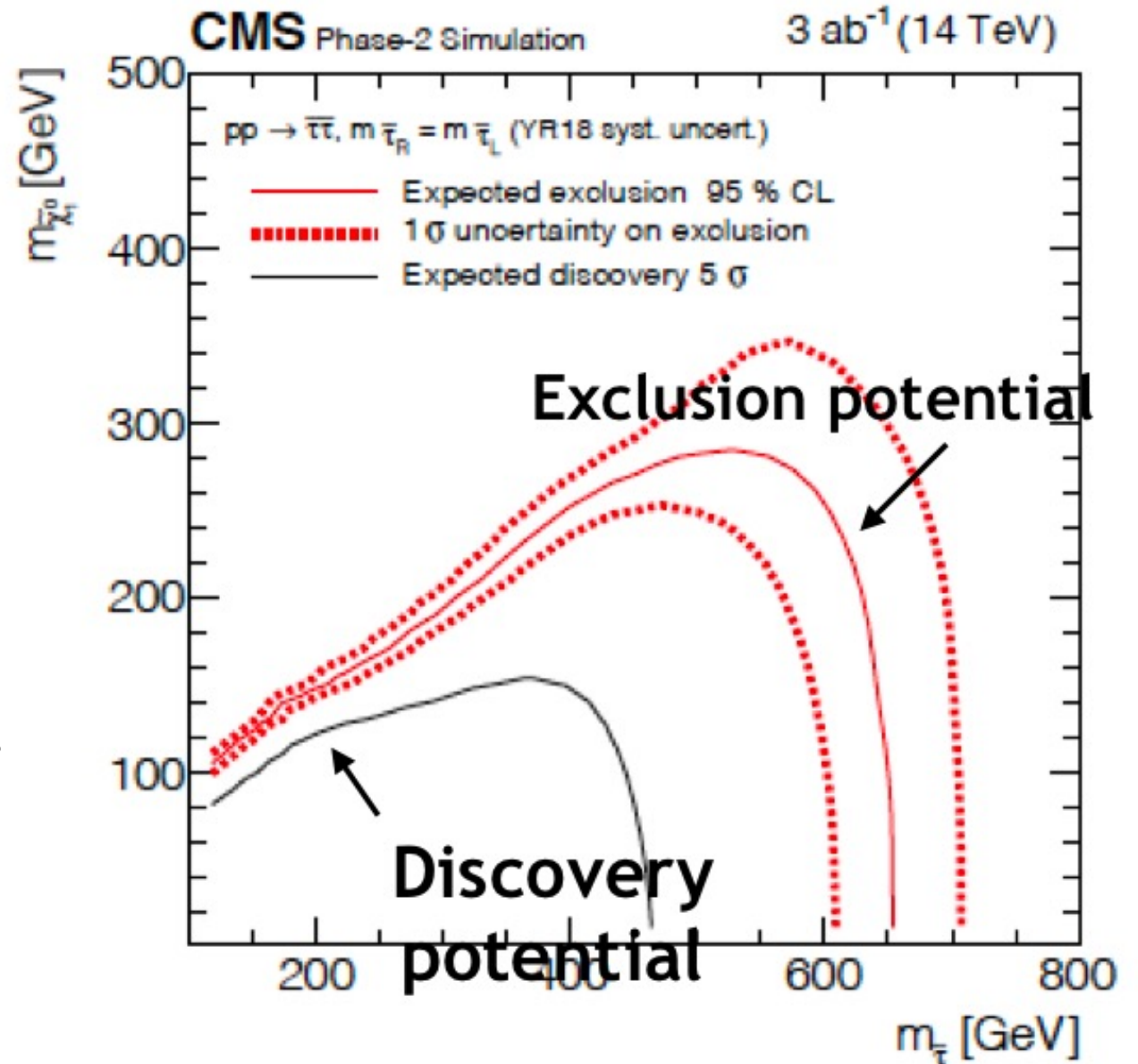
Backup

CMS detector

Silicon Tracker

Electromagnetic Calorimeter

Hadron Calorimeter

Superconducting Solenoid

Iron return yoke interspersed with muon chambers

— Muon
— Electron
— Charged hadron (e.g. pion)
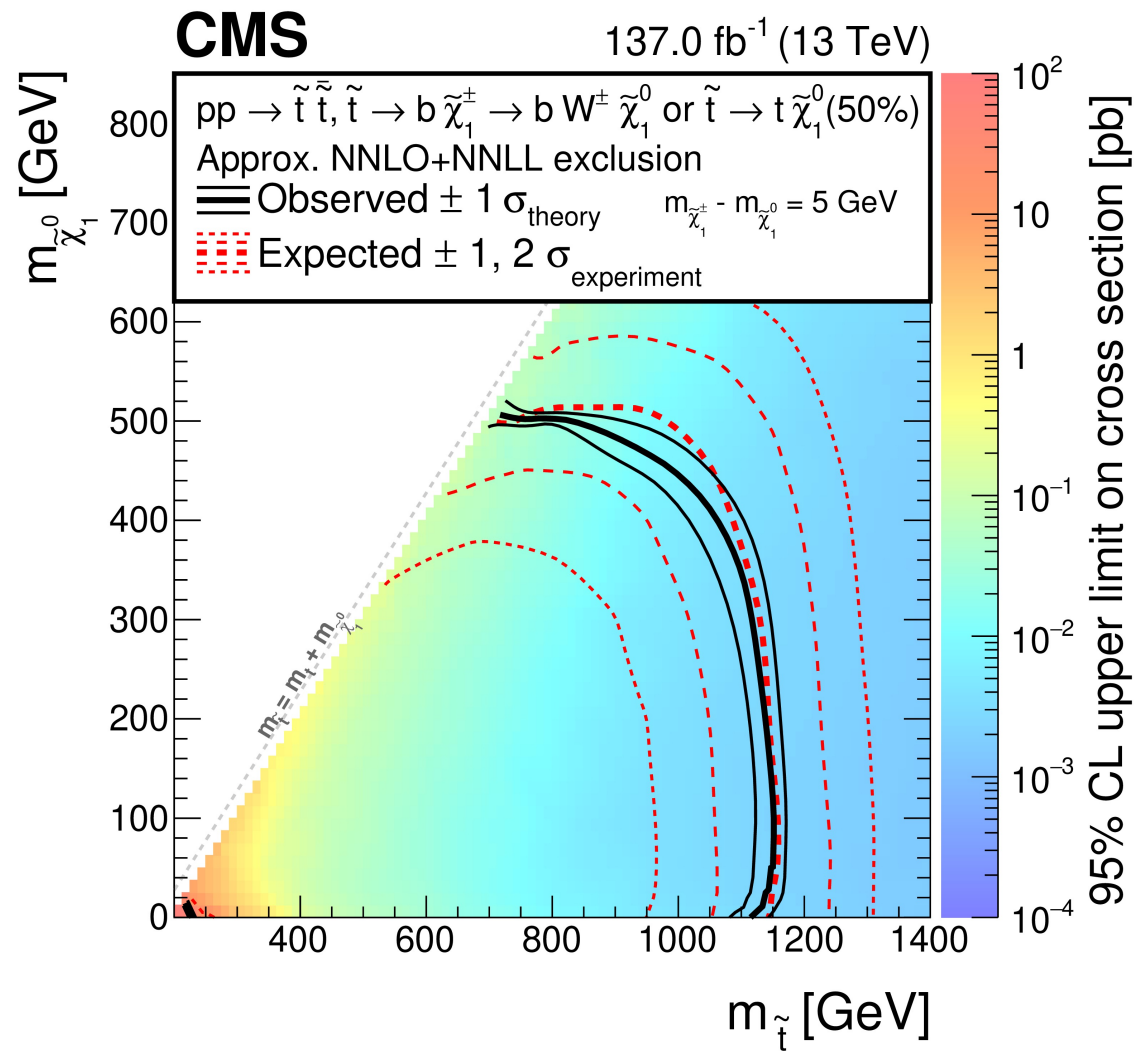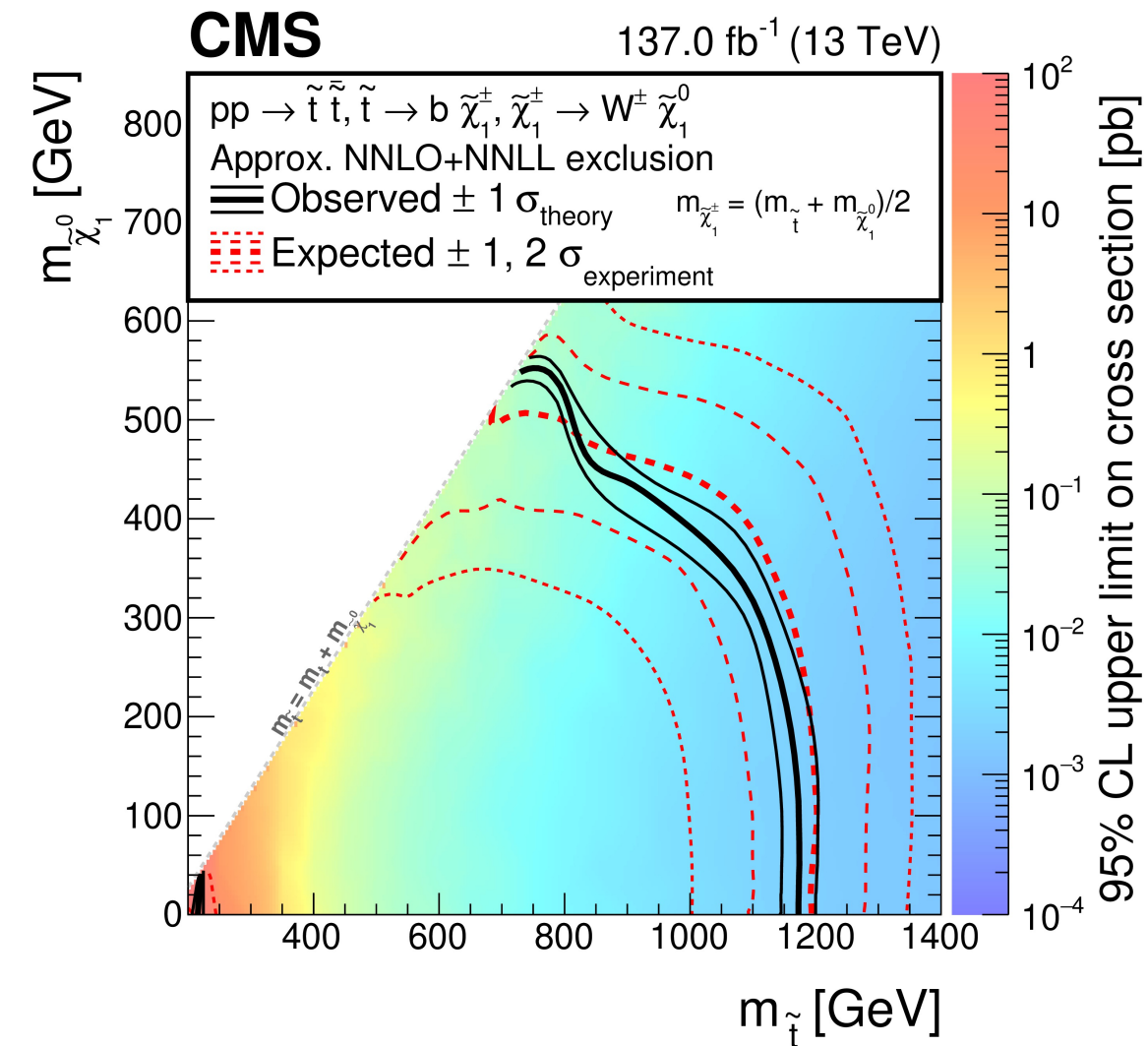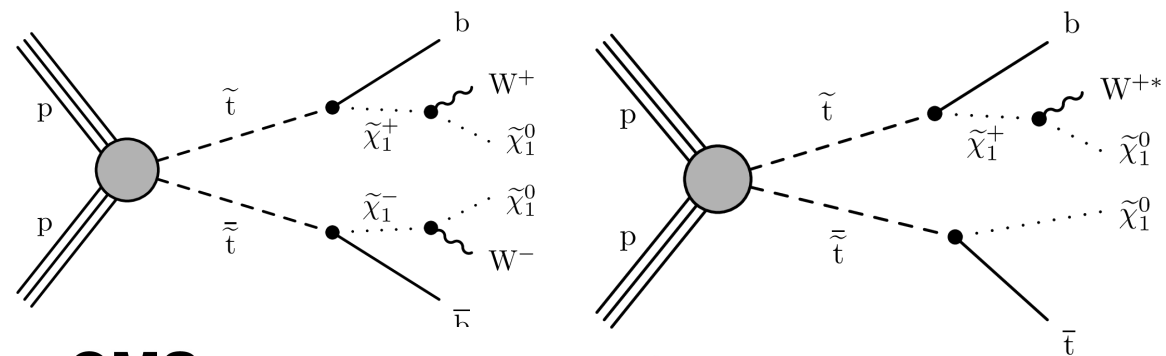---- Neutral hadron (e.g. neutron)
---- Photon

HL-LHC

Projection for tau slepton discovery and exclusion using a simplified version of the analysis.
Potential to improve even more with more sophisticated analysis techniques

Results for T2bW and T2tb

Results for T2bWC, T2cc and T2ttC