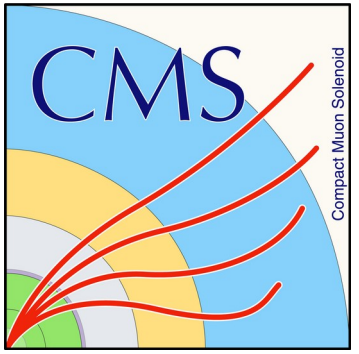

SUSY in the top quark corridor in CMS

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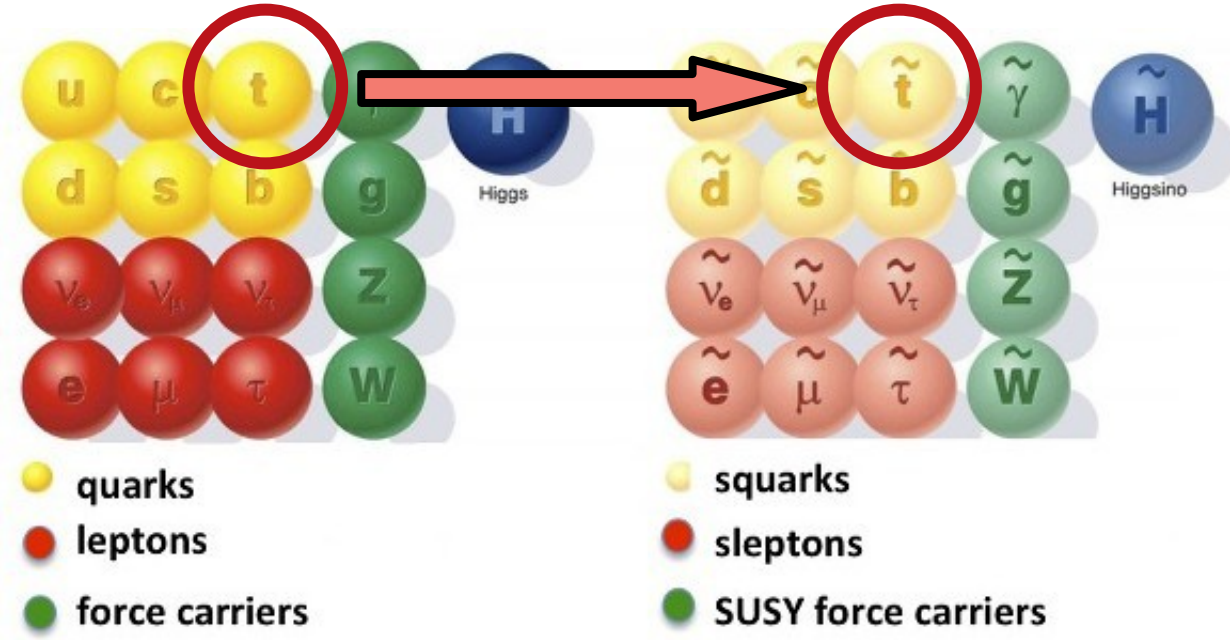
Universidad de Oviedo / ICTEA

May 10, 2021

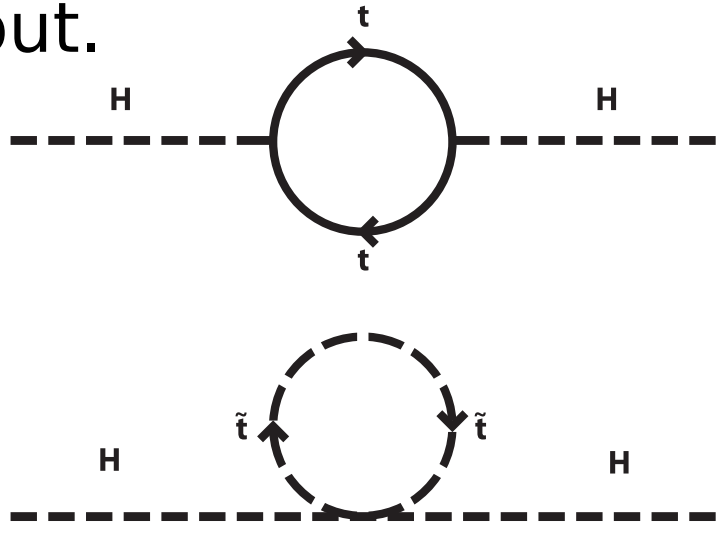
5th RED LHC workshop

Why SUSY and top quarks?

Supersymmetry introduces a symmetry between bosons and fermions. Several new particles may be there.



The SM fine tuning on higgs mass is solved: contributions from top and stop can cancel out.

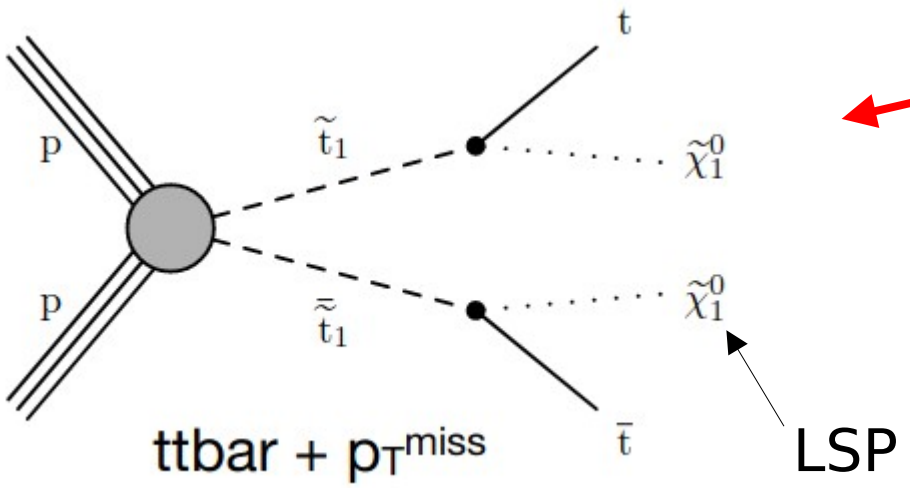


- Natural SUSY ↔ ~low levels of fine tuning.

What if $\mathbf{m(\tilde{t}_1) \simeq m(t)}$?

A new result: CMS-PAS-SUS-20-002

Top squark searches by CMS

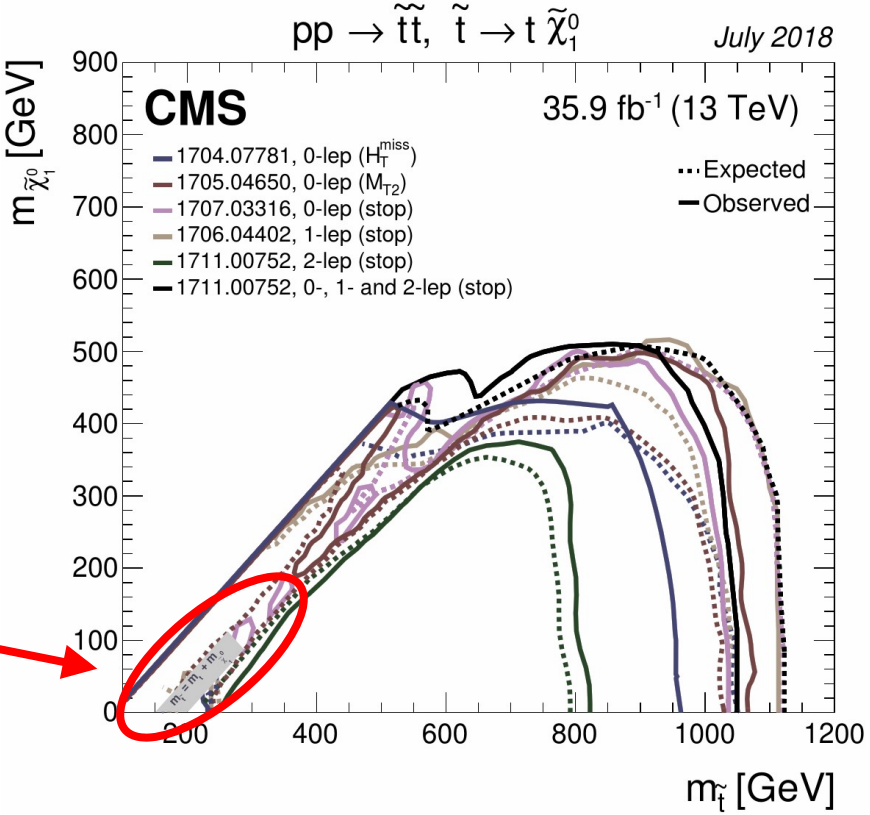


Golden channel.

When $m(\tilde{t}_1) \simeq m(t)$ and $m(\tilde{\chi}_1^0)$ is small, the experimental signature is very similar to SM $t\bar{t}$.

This special region:
"top quark corridor",
defined by:
$\Delta m = [m(\tilde{t}_1) - m(\tilde{\chi}_1^0)] \simeq m(t)$,
and $m(\tilde{\chi}_1^0) \lesssim 100$ GeV.

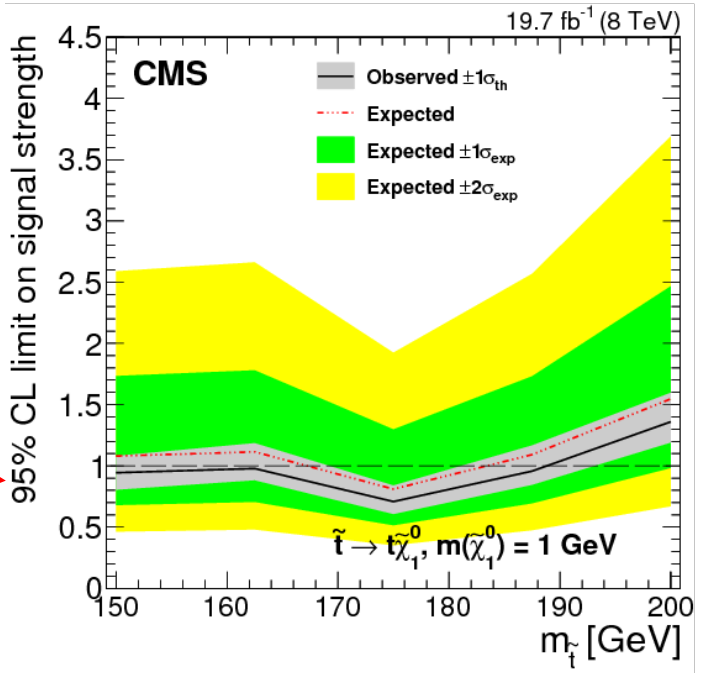
Blanked in CMS general searches. Needs a special treatment (MC simulation, analysis strategy...).



Previous results

Stop quarks in the top corridor can be seen as an excess on the SM top quark cross section.

Sensitivity to massless neutralinos, at 8 TeV.



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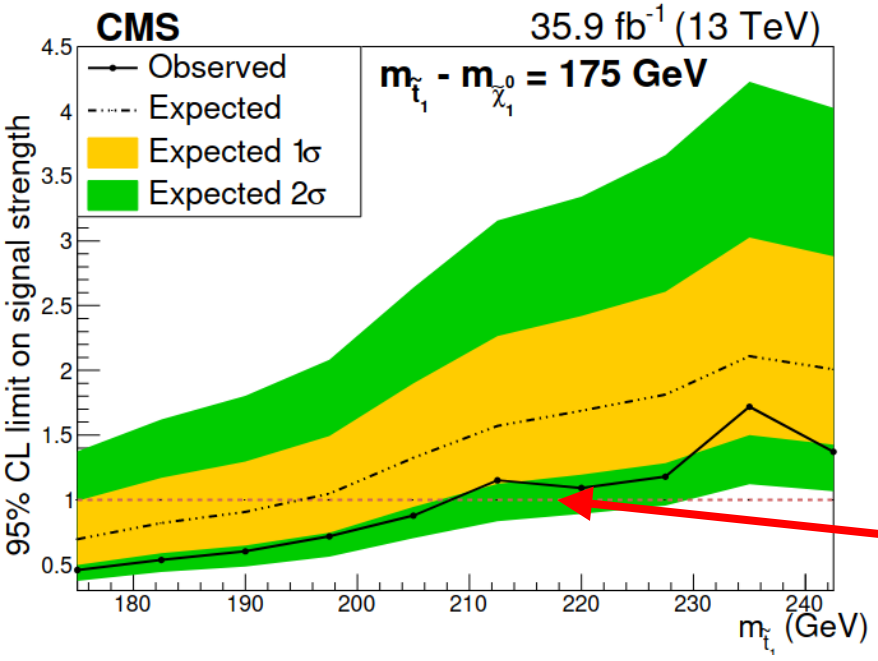

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The sensitivity has been extended at 13 TeV by adding new data and small kinematic differences for higher stop/neutralino masses.

Exclusion up to $m(\tilde{t}_1) \simeq 208$ GeV.

New analysis with full Run2 data

Goal: sensitivity to higher m($\tilde{t}_1$),m($\tilde{\chi}_1^0$), up tp about m($\tilde{t}_1$)=280 GeV.

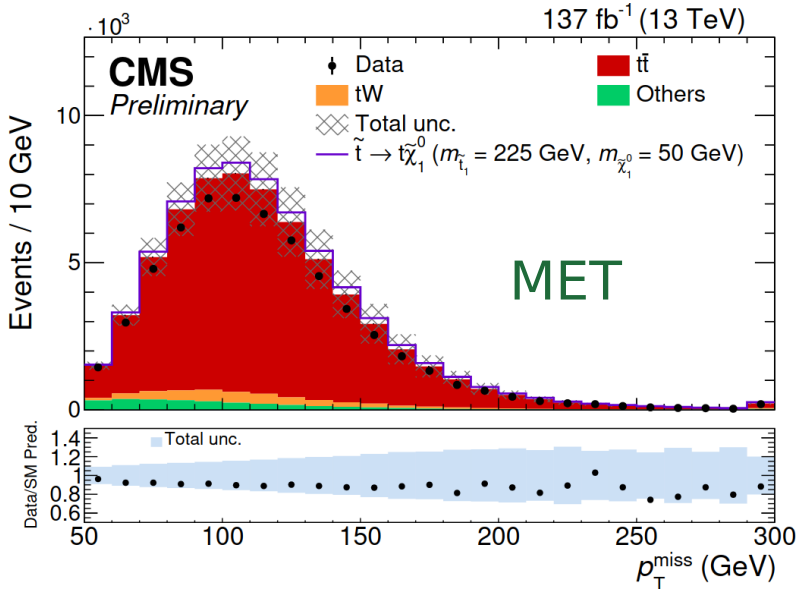
CMS-PAS-SUS-20-002

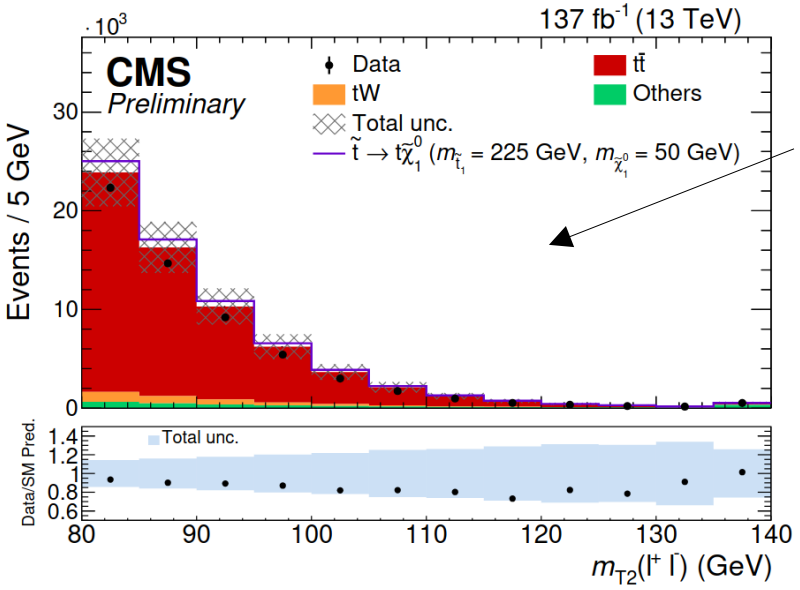
Baseline selection: dilepton events, at least 2 jets, at least one b-tagged jet – very $t\bar{t}$-like phase space.

Signal region:

- Signal neutralinos contribute to the missing transverse momentum (MET) in the event → MET > 50 GeV.
- M_{T2} is computed: observable with an endpoint for $t\bar{t}$ and not for signal, due to the presence of neutralinos → M_{T2} > 80 GeV.

$$M_{T2}^2 = \min_{p_{T1}^{miss}+p_{T2}^{miss}=E_T^{miss}} \left(\max \left[m_T^2(p_T^{\ell 1}, E_T^{miss}), m_T^2(p_T^{\ell 2}, E_T^{miss}) \right] \right)$$



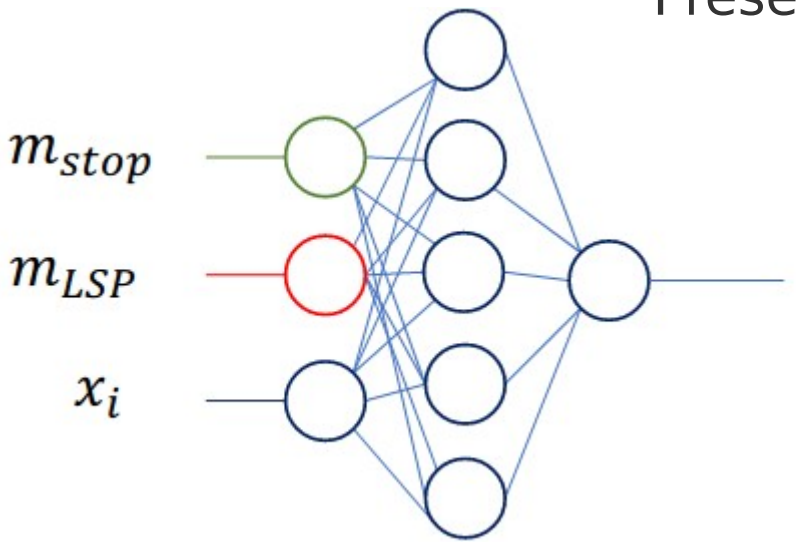


Background events, estimated from MC simulation, come mainly from $t\bar{t}$.

Strategy: parametric neural network

To increase the sensitivity to signal, a parametric deep neural network (DNN) is trained to learn small kinematic differences.

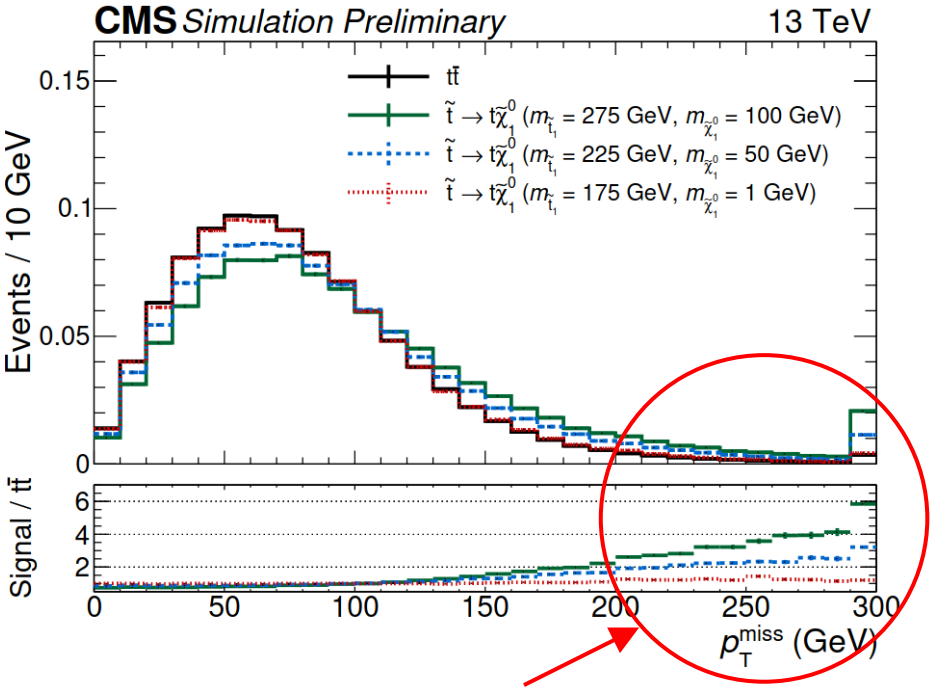
Presented at COMCHA meeting by A. Trapote.



$$f(m_{stop}, m_{LSP}, x_i)$$

Stop and neutralino masses are used in the training – A single MVA model is optimize for each signal parameter space point.
Different kinematics depending on the signal model:

- $\Delta m \simeq m(t)$, $m(\tilde{\chi}_1^0) \simeq 0$
- $\Delta m \simeq m(t)$, $m(\tilde{\chi}_1^0) > 0$
- $|\Delta m - m(t)| > 0$

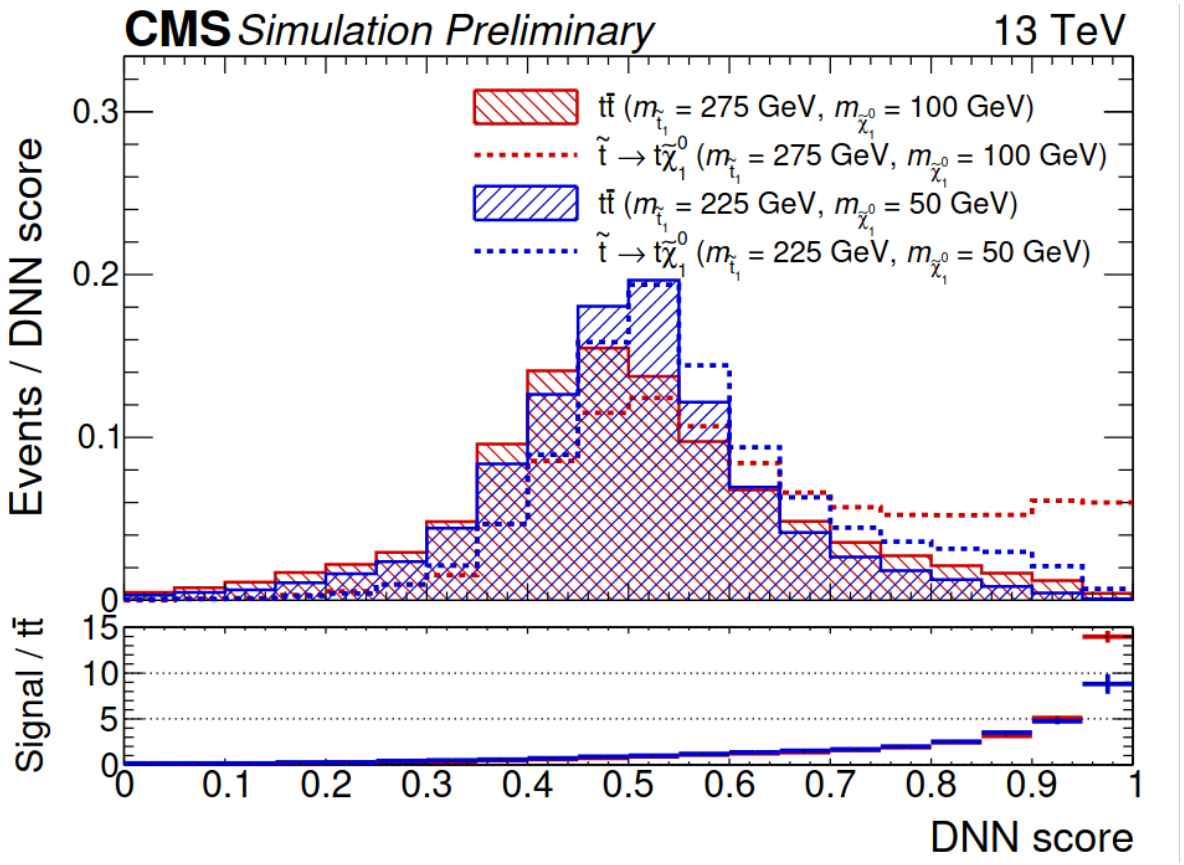


Signal models with different masses have different behaviors

Strategy: parametric neural network

Stop signal trained against SM tt background using events after the baseline selection. 13 training variables:

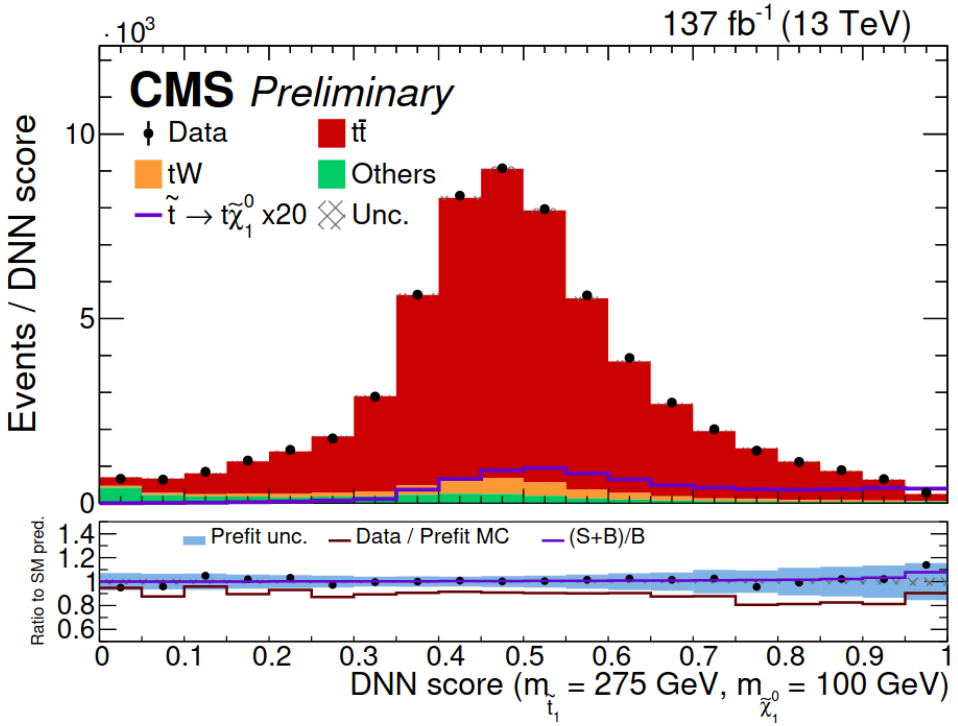
$$m_{stop},\ m_{LSP},\ p_T^{e\mu},\ \Delta\phi,\ \Delta\eta,\ p_T(l_0),\ \eta(l_0),\ p_T(l_1),\ \eta(l_1),\ p_T^{miss},\ m_{e\mu},\ m_{T2}(e\mu),\ H_T$$

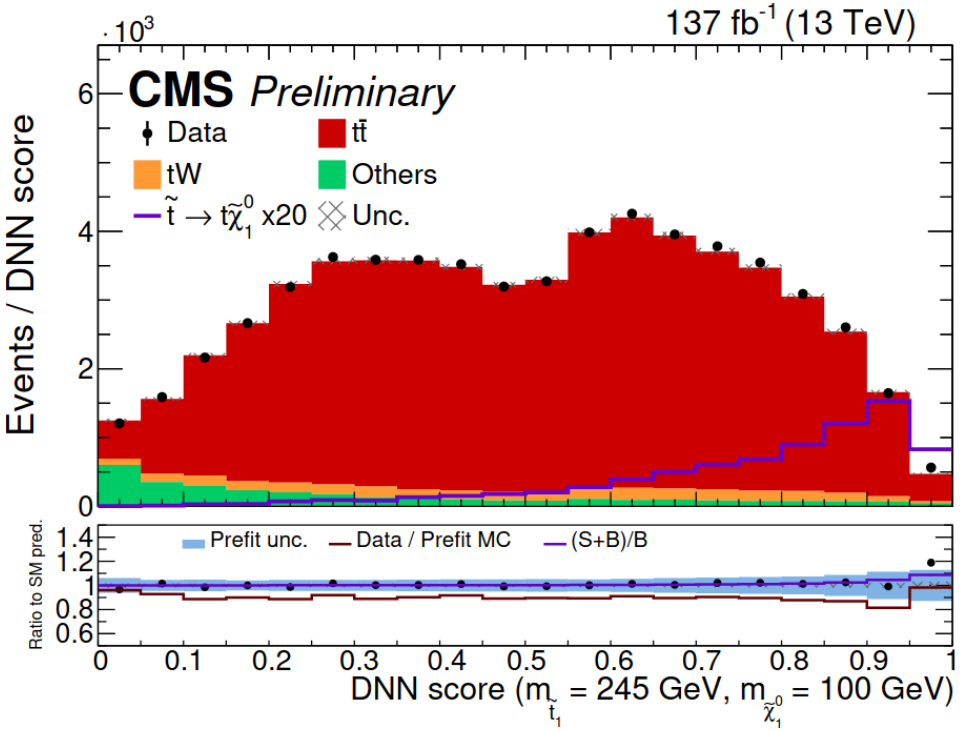


Neural network discriminant applied on events in the signal region. Discrimination achieved at high DNN score, largely dependent on the signal model masses. We have a different signal and background distribution for each mass.

PLR fit to data

- Modeling uncertainties are estimated for the tt background prediction, including ME/PS scales and matching, PDF, α_S, top quark mass, underlying event tune.
- Experimental uncertainties are important due to resolution effects affecting MET and M_{T2}, especially the jet energy scale and resolution.
- The uncertainties are propagated to the DNN distribution, which is used to compare SM and signal hypothesis with the observation.
  A profile likelihood fit is performed, where systematic uncertainties are constrained.

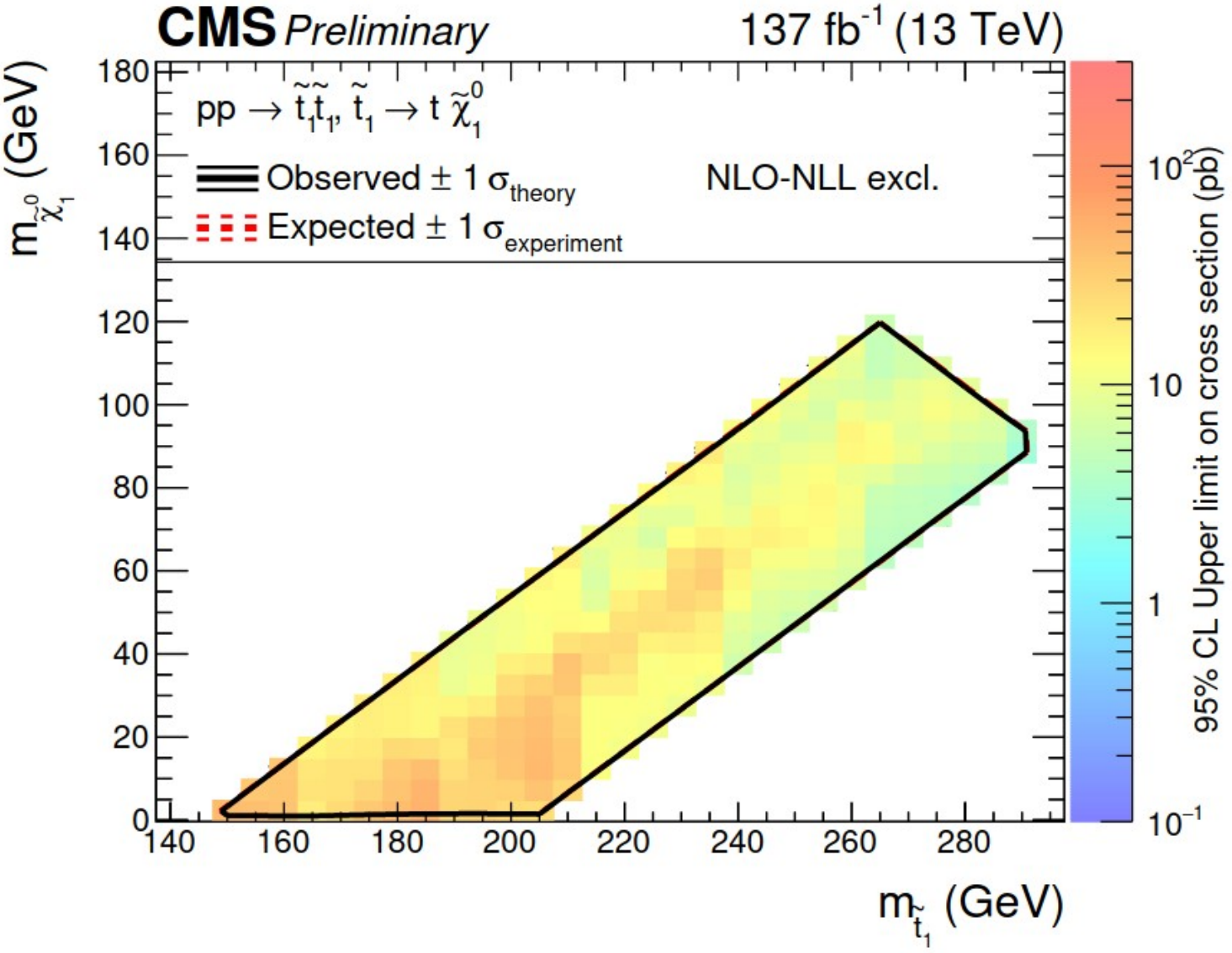




No excess is observed over the background prediction.

Results

Upper limits are set to the signal cross section.
The presence of the signal is excluded at 95% CL in the whole explored region of the parameter space.



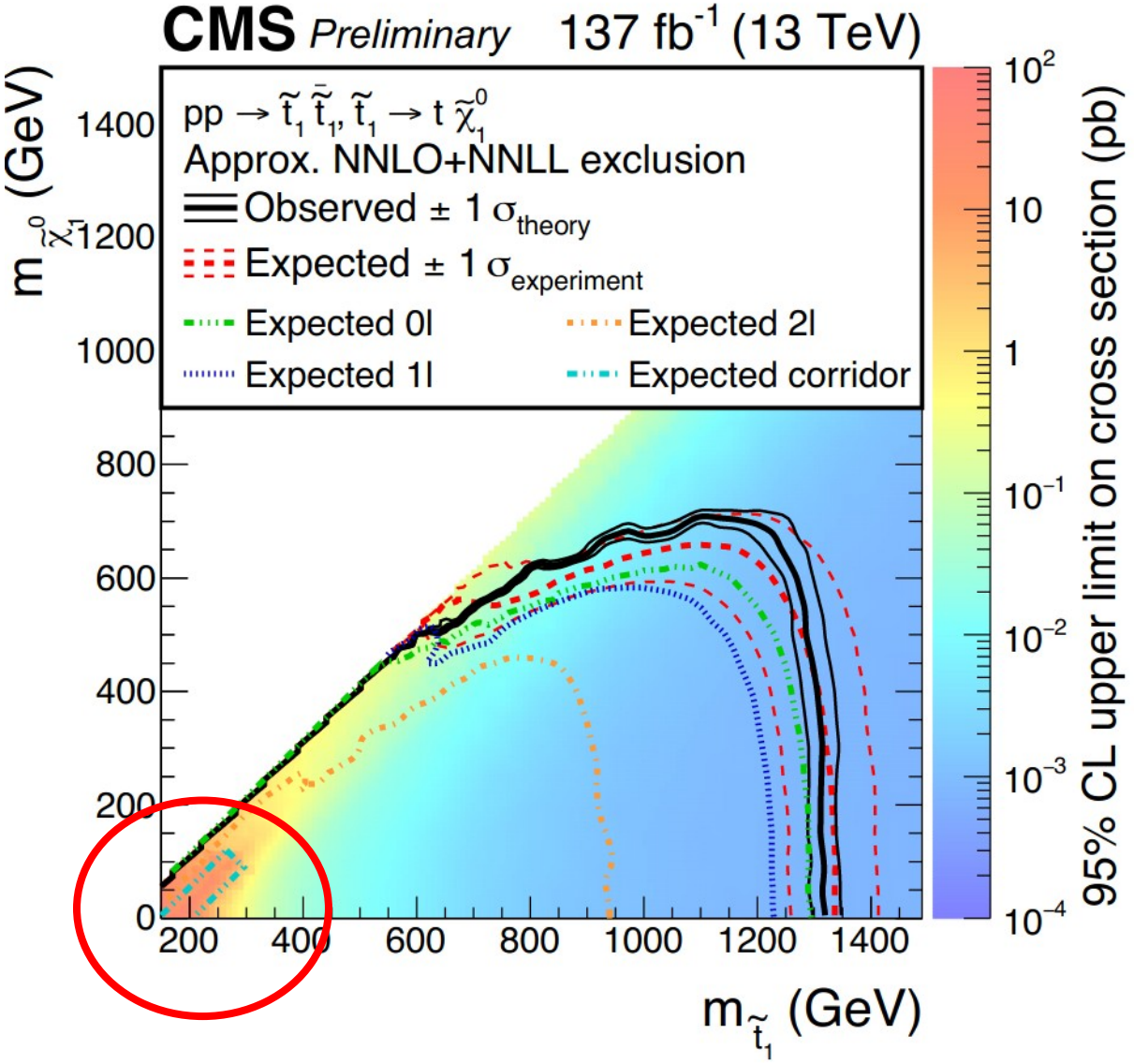
Run 2 legacy combination

Run 2 searches for SUSY top quark partners are combined (0-lep, 1-lep, 2-lep).

[CMS-PAS-SUS-20-002]

Stop production excluded up to masses of about 1350 GeV.

More models, including dark matter interpretation, can be found in the backup slides.

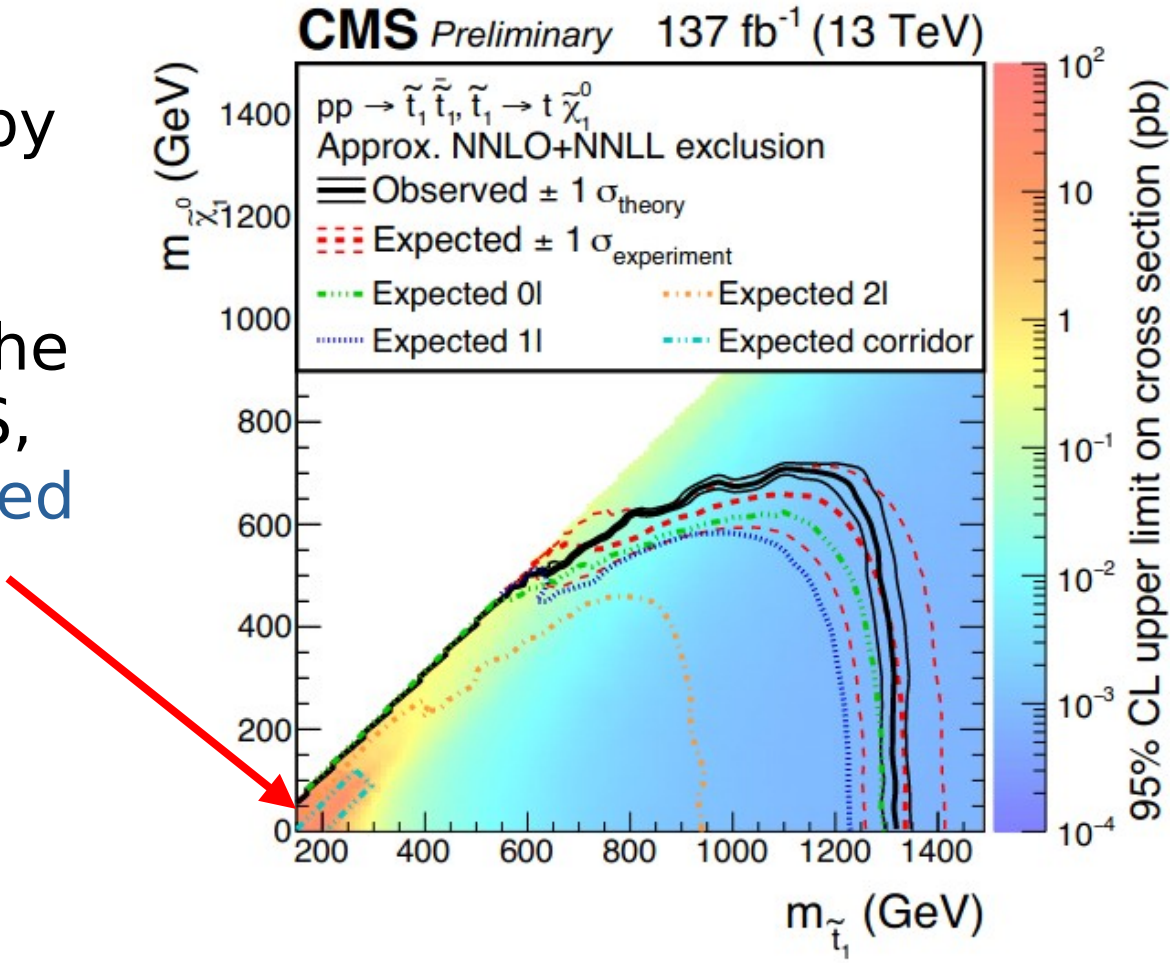


Summary

A dedicated search for supersymmetric top quark partners has been performed for this particular region of the parameter space in which the mass difference between stop and neutralino is close to the SM top quark mass, resulting in very similar kinematics.

This region is completely excluded for the first time by CMS.

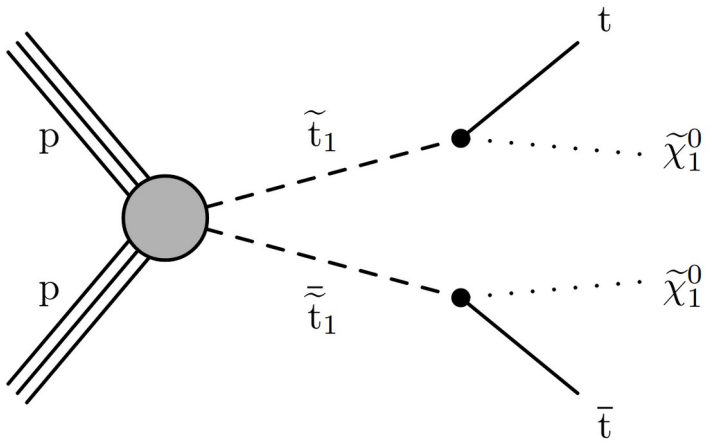
This search complements the stop quark searches in CMS, which have now fully covered a wide range of masses.

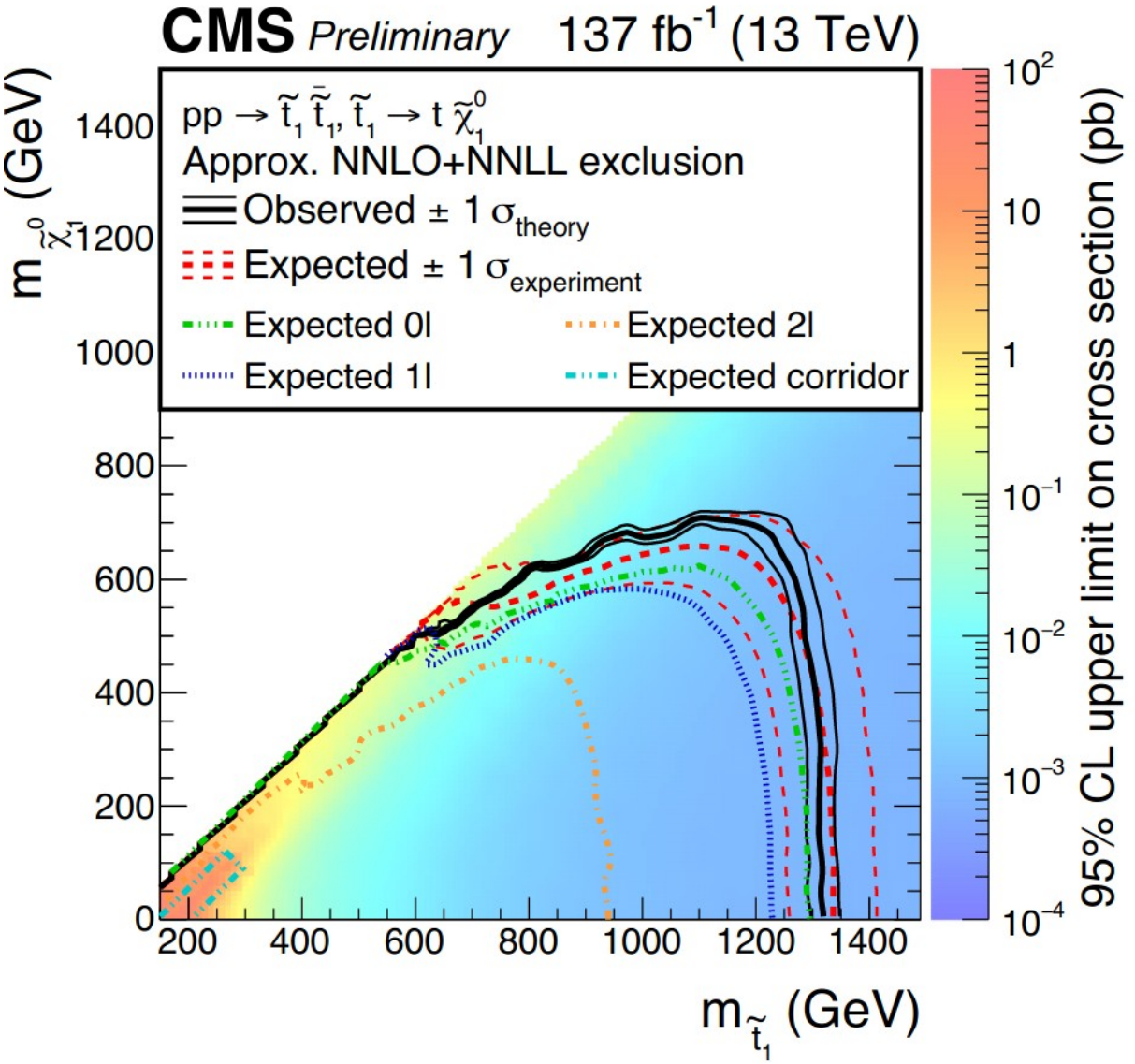


BACK UP SLIDES

Run 2 legacy combination

$\tilde{t} \rightarrow t\tilde{\chi}_1^0$ model





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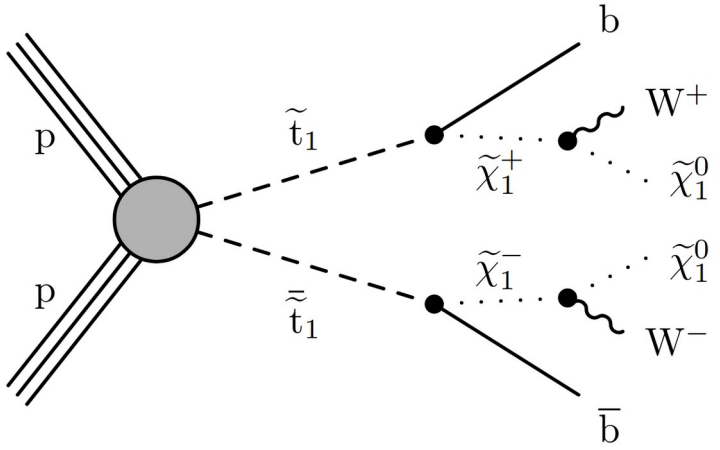
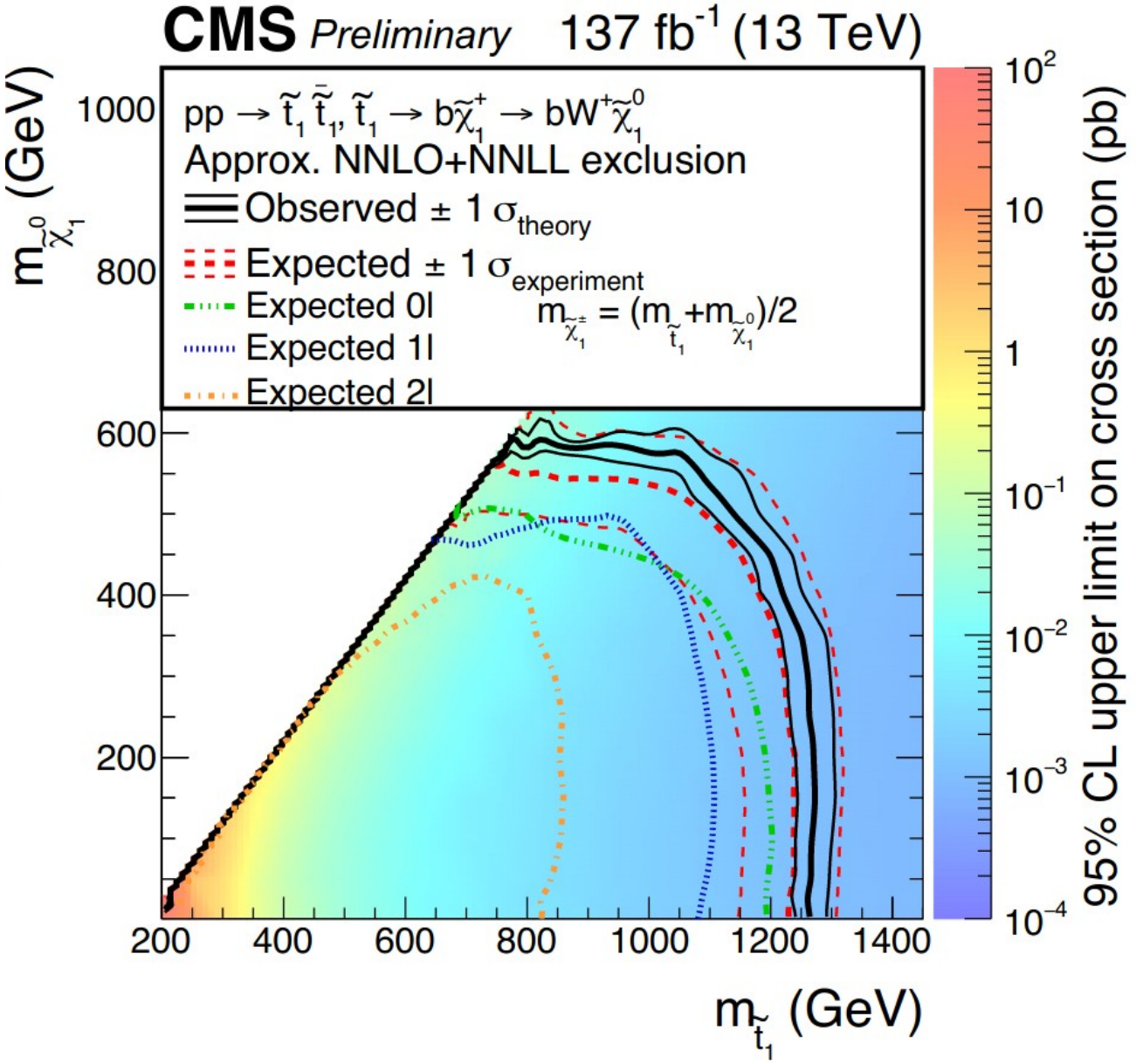
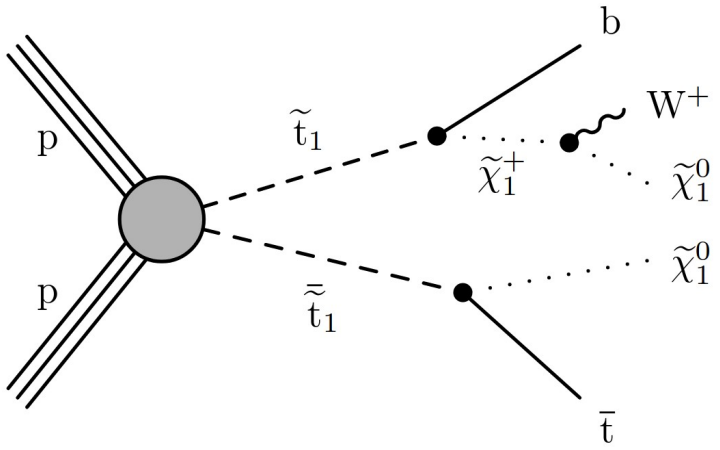
Run 2 searches for SUSY top quark partners are combined (0-lep, 1-lep, 2-lep).

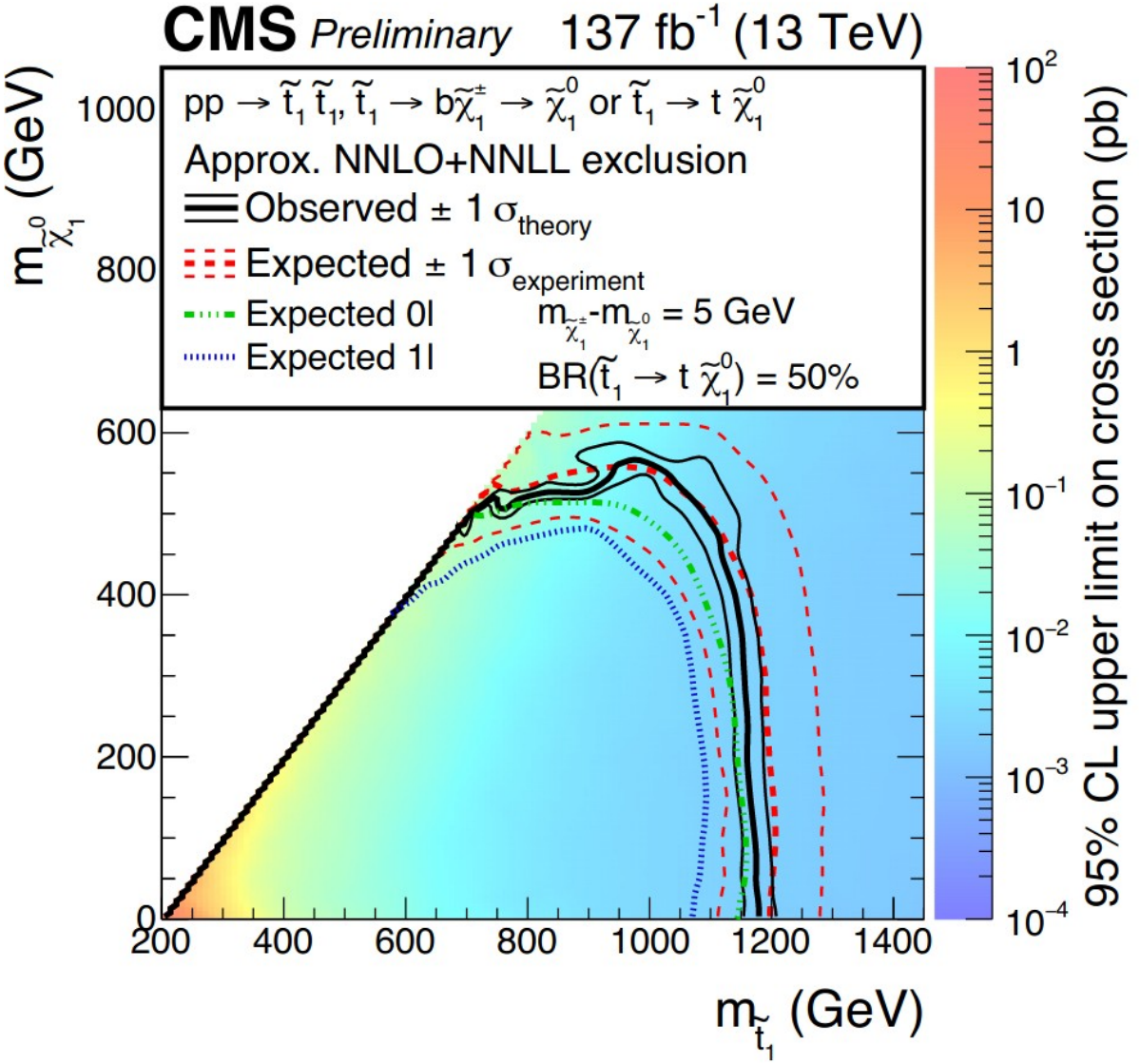




Run 2 legacy combination

$\tilde{t}_1 \to b\tilde{\chi}_1^+ \to bW^+\tilde{\chi}_1^0$ model





Dark matter interpretation

Dark matter search interpretation for 1 GeV DM particle and scalar or pseudoscalar mediator.