UNIVERSITY OF CALIFORNIA
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Search for third generation squarks in 13 TeV pp collisions at CMS

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on behalf of the CMS collaboration

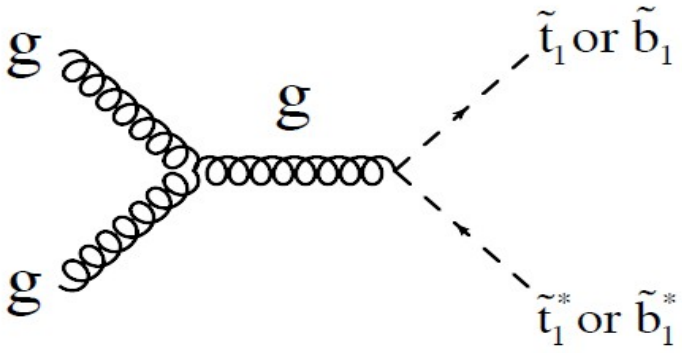
Third generation susy

- Motivations:
  - Naturalness usually requires low squark mass (<1 TeV) to cancel radiation corrections to Higgs masses.
  - 3^{rd} generation quarks can be lighter than all squarks due to large mixing.
- CMS has a broad 13 TeV 3^{rd} generation search program:
  - Diverse selection of signal topologies, classified in produced sparticles and decay channels;
  - Inclusive and dedicated searches, spanning many decay signatures (lepton multiplicity).
- Interpretation of analyses are made with Simplified Model Spectra.

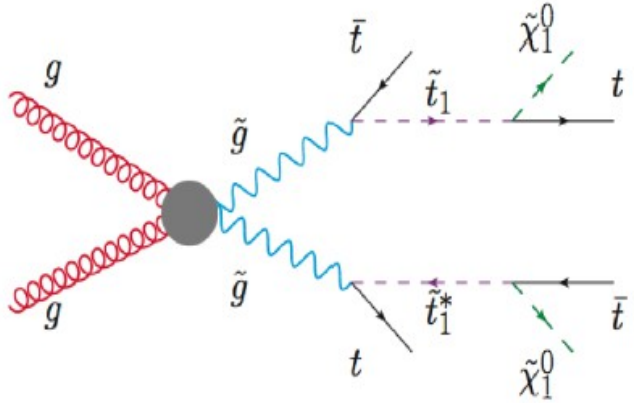
Production mechanisms

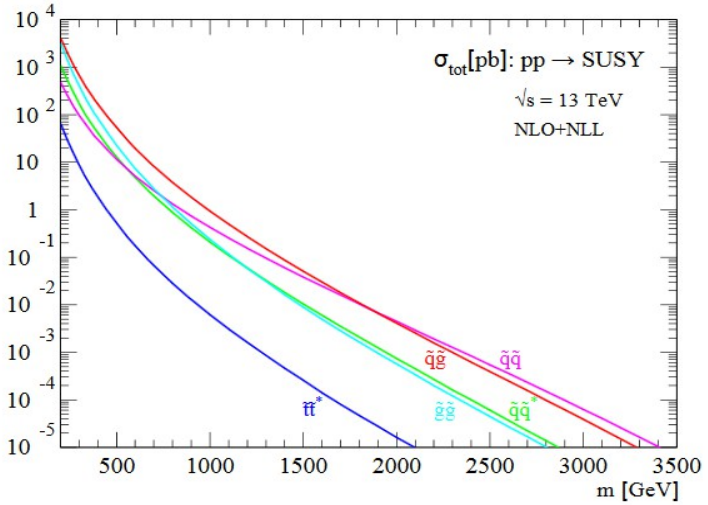
- Stop and sbottom quarks can be produced in LHC collisions via:
  - Direct squark pair production by gg fusion or $q\bar{q}$ annihilation;
  - Gluino mediated production.

Direct production



Gluino mediated production



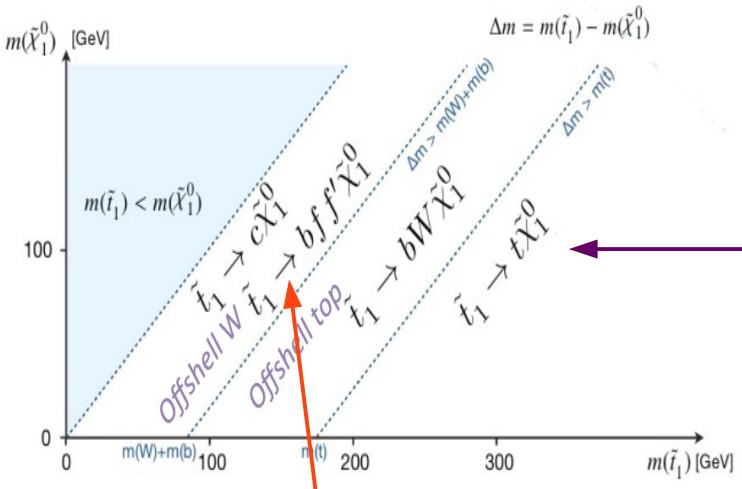


- Production cross-section rapidly falls with mass.
- ~150 events expected in 2015 dataset for 700 GeV squarks in direct production.

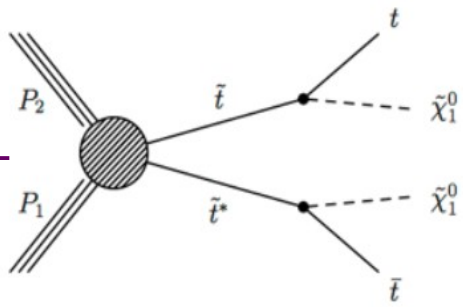
- For heavy stop, look at 8 TeV SUS-13-024

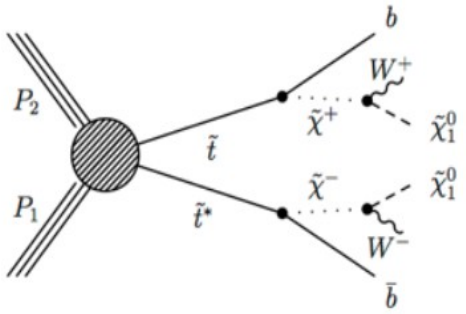
Direct stop production

- Different decays depending of the stop and LSP masses:



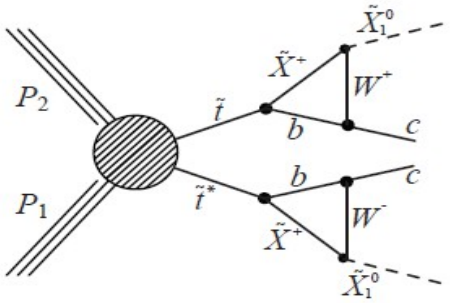
- Direct LSP decay, chargino decay:

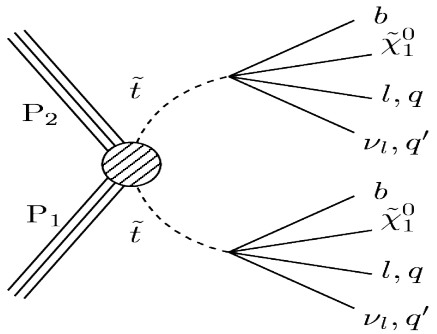




→ 0-lepton (SUS-16-007), 1-lepton (SUS-16-002), inclusive analyses (SUS-15-002, SUS-15-003)

- C through loop, 4-body decay:





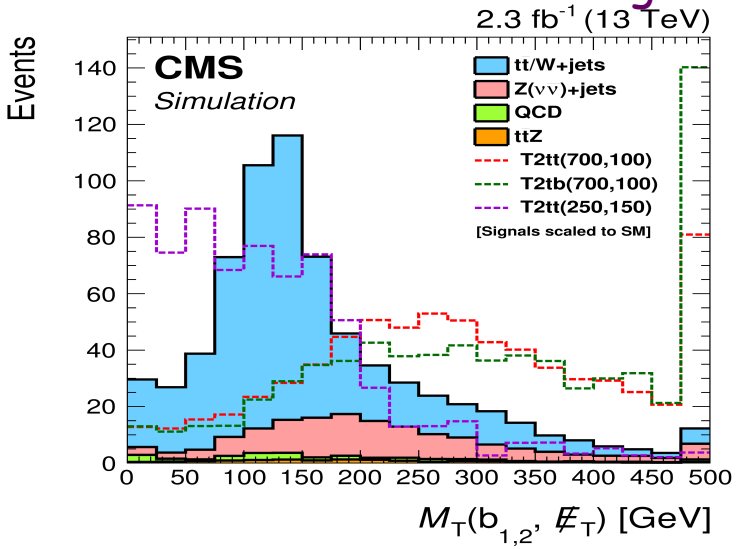
→ Soft lepton analysis (SUS-16-011)

Dedicated 0 lepton analyses

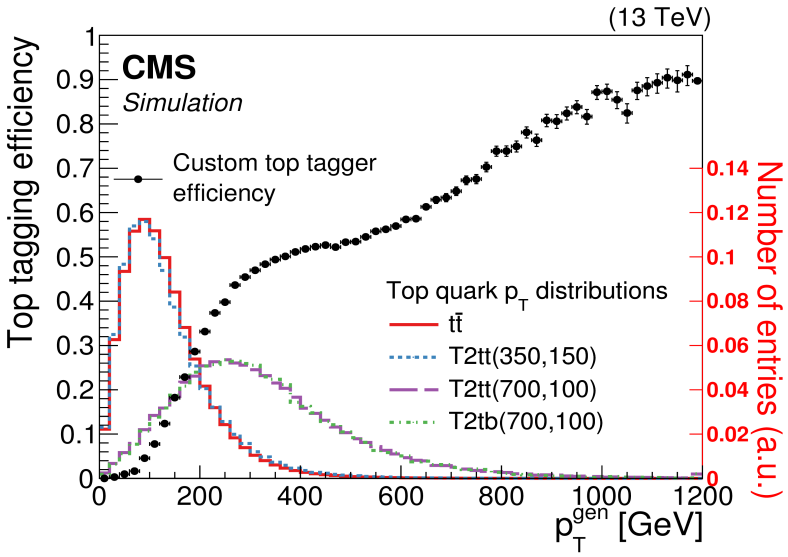
- Two 0 lepton analyses looking for direct stop production:

SUS-16-007

- High **Purity** Top Tagging (HPTT):
  - Aimed at compressed $\tilde{t} \to t\tilde{\chi}^0$ and $\tilde{t} \to b\tilde{\chi}^{\pm}$ decays
  - Use CMS top tagger with ak8 jets, top p_T>400 GeV
  - Categorization of events in orthogonal bins of kinematic variables
    - M_T(b, MET), Njets, Nbjets, presence of top, MET
    - Total of 50 search regions



- High **Efficiency** Top Tagging (HETT):
  - Aimed at medium and large Δm between m(stop) and m(LSP)
  - Use custom, highly efficient top-tagger
    - Test various combination of three ak4 jets of at least 30 GeV in a cone of radius 1.5
  - Categorization of events in bins of Ntop, Nbjets, MET and MT2.

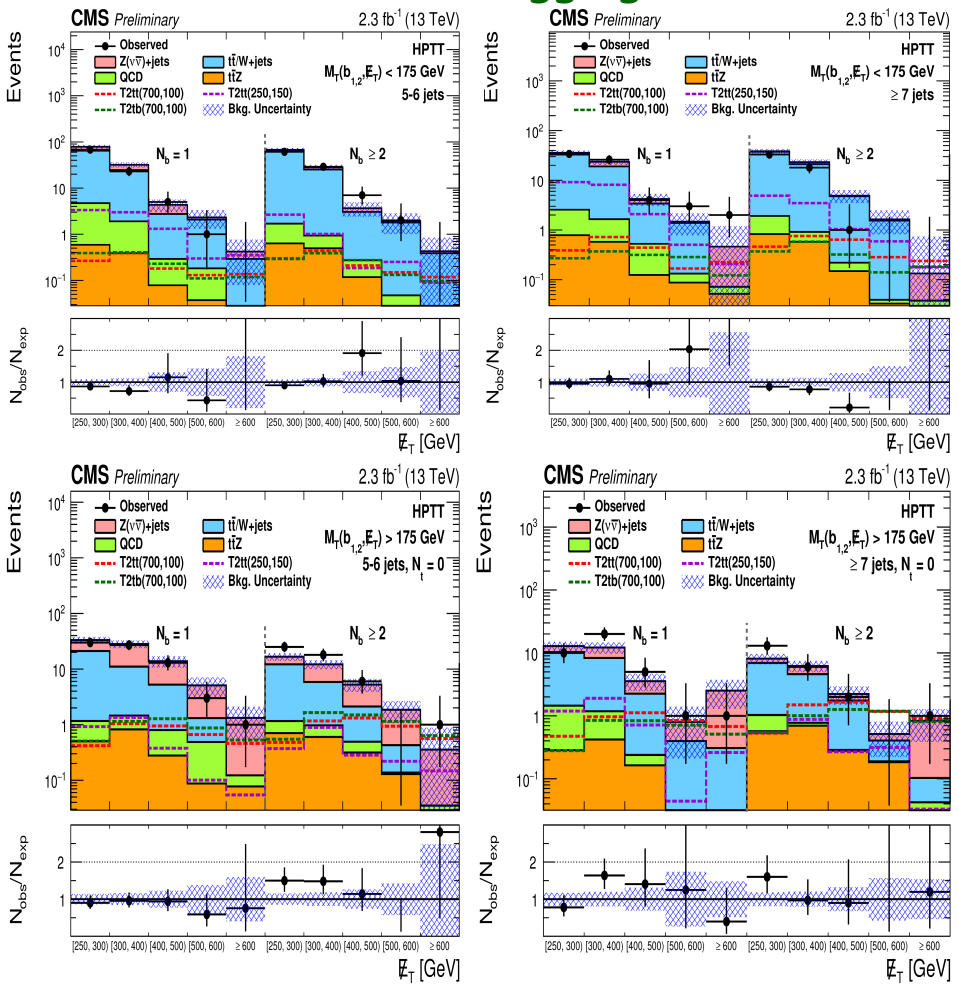


Backgrounds estimation

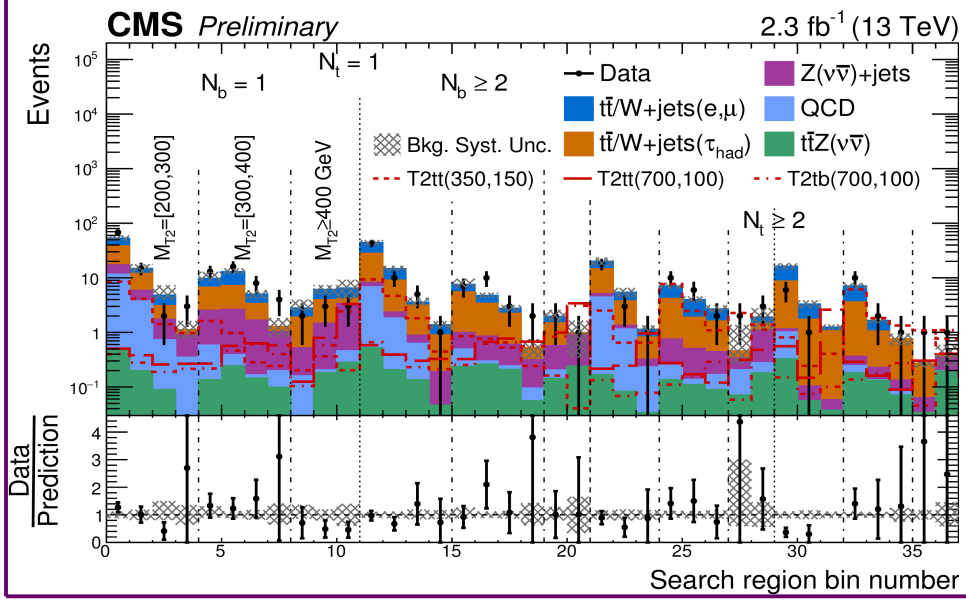
- TTbar, W+jets and single top
  - With lost lepton(s)
    - From muon+jets control sample, correcting for lepton efficiency (HETT) or using a translation factor (HPTT)
  - With hadronic tau (HETT)
    - From muon+jets control sample, replacing the muon p_T by the tau jet p_T using templates
- $Z \rightarrow \nu\nu$+jets:
  - $Z \rightarrow ll$+jets (normalization) and γ+jets (shape) control region used for HPTT
  - $Z \rightarrow \mu\mu$ used for HETT
- QCD
  - From inverted deltaPhi and low MET control region, using translation factors
- ttZ and other rare backgrounds
  - Estimated with MC, checks in data

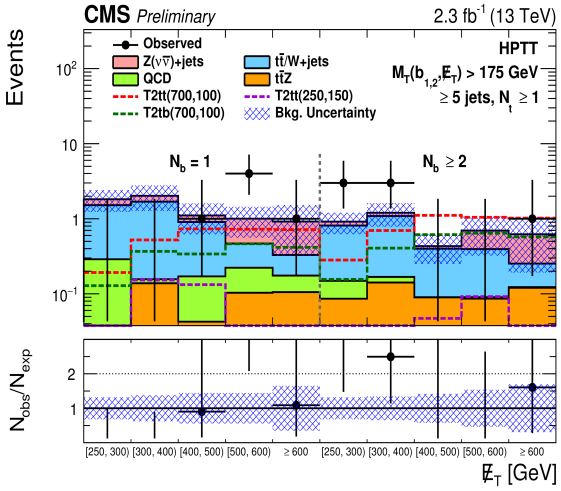
Results of the 0 lepton analyses

- High **Purity** Top Tagging (HPTT)



- High **Efficiency** Top Tagging (HETT)

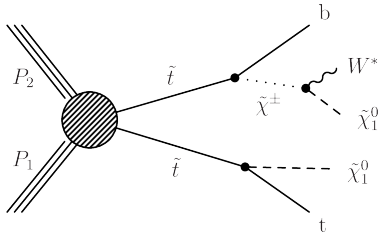


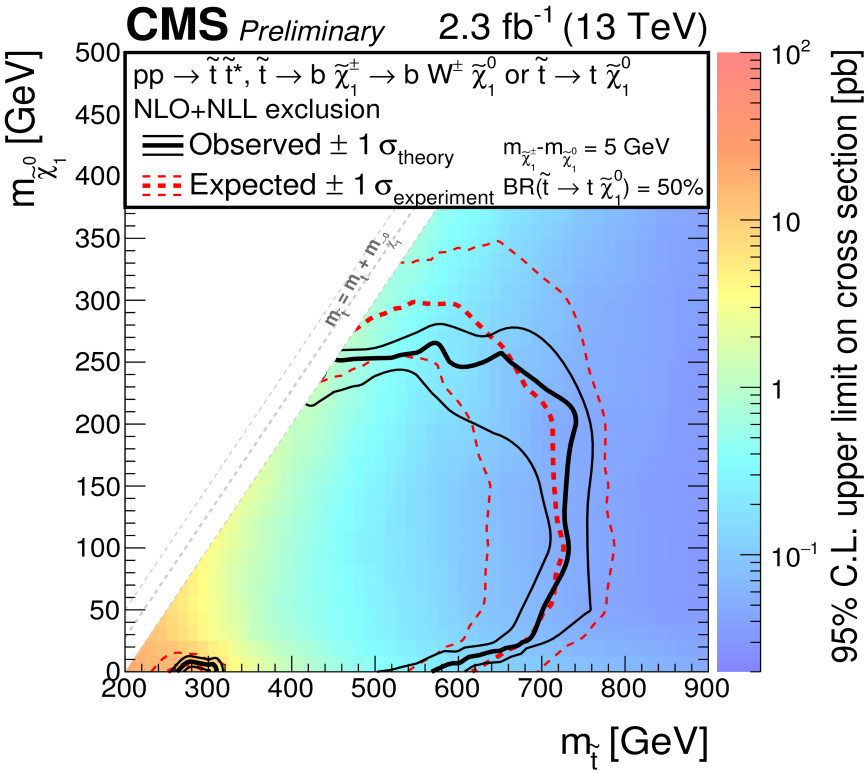


- No significant excess observed in the 2.3 fb^{-1} of data for the 2 analyses.

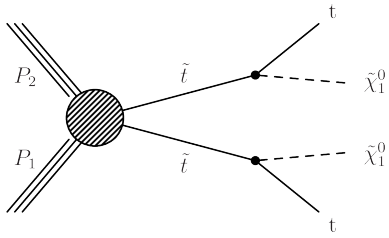
Interpretations of the 0 lepton analyses

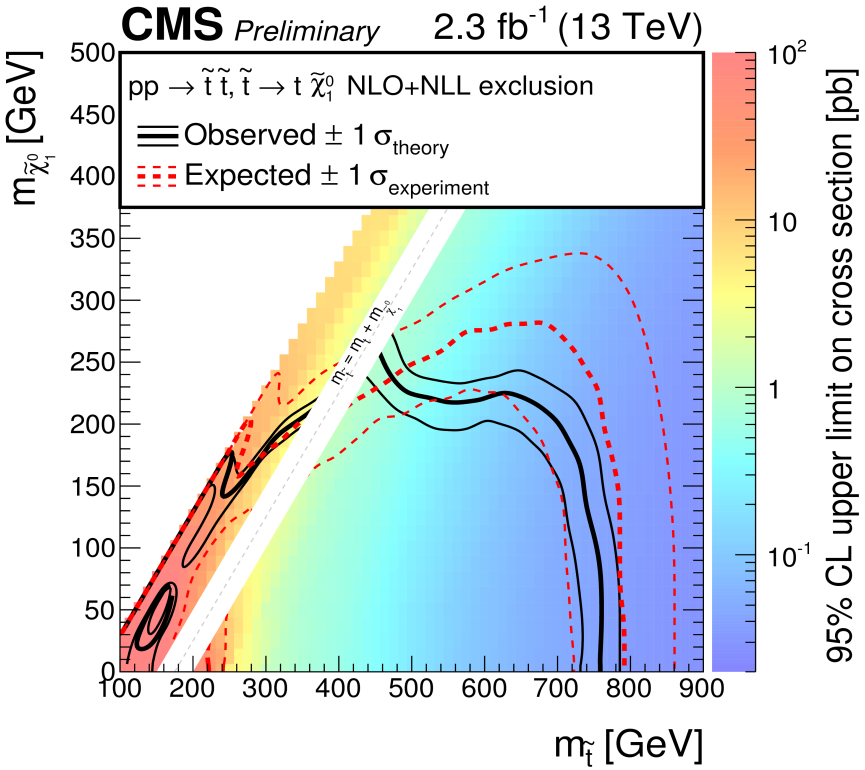
- HPTT





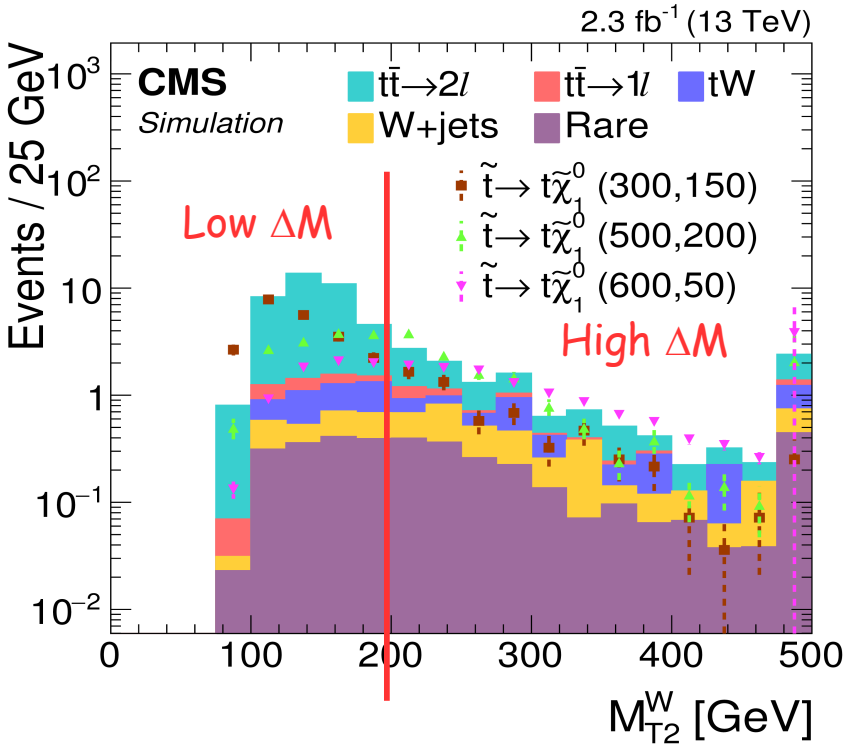
- HETT

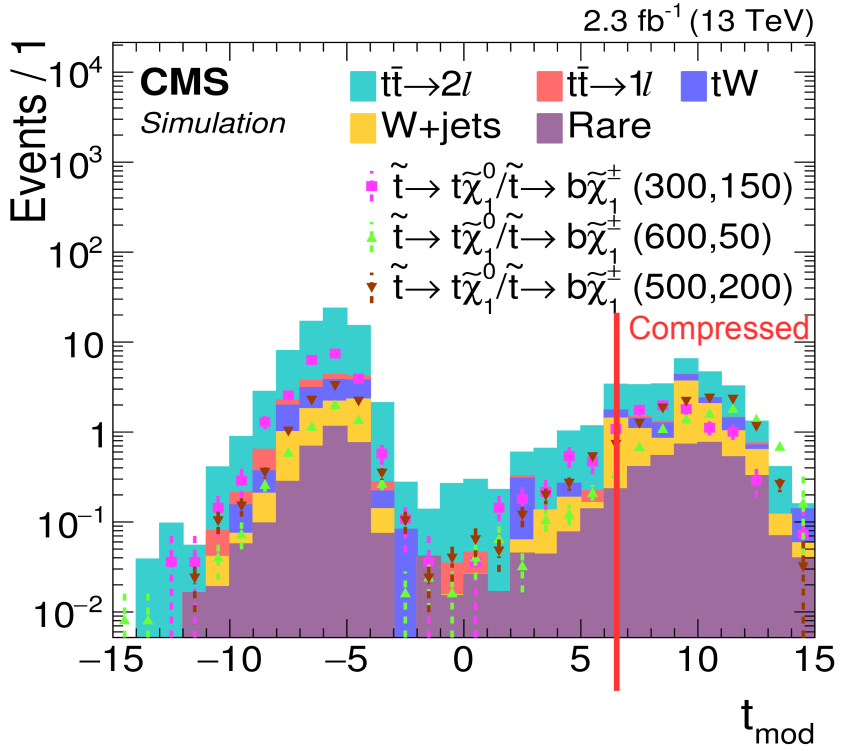




The 1 lepton stop analysis

- Use MT2W or modified topness variables to define search regions: SUS-16-002

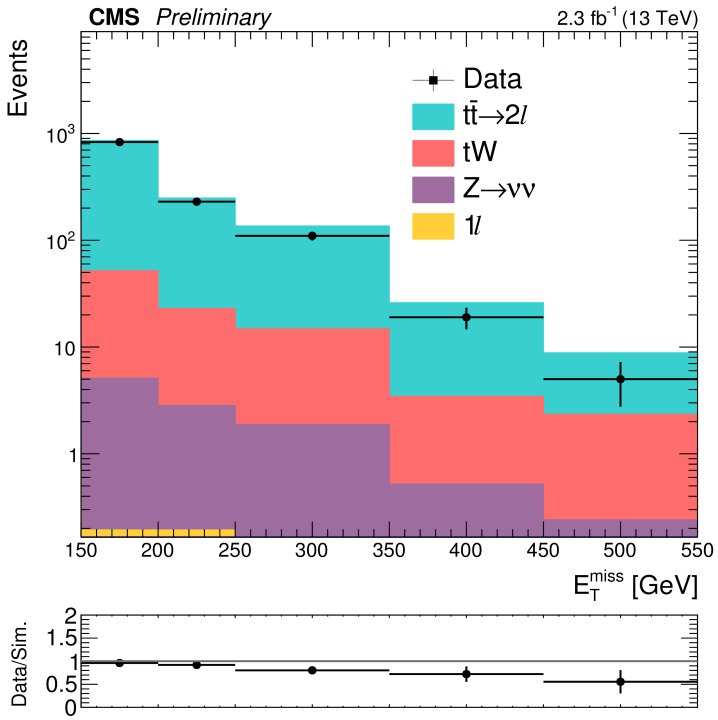


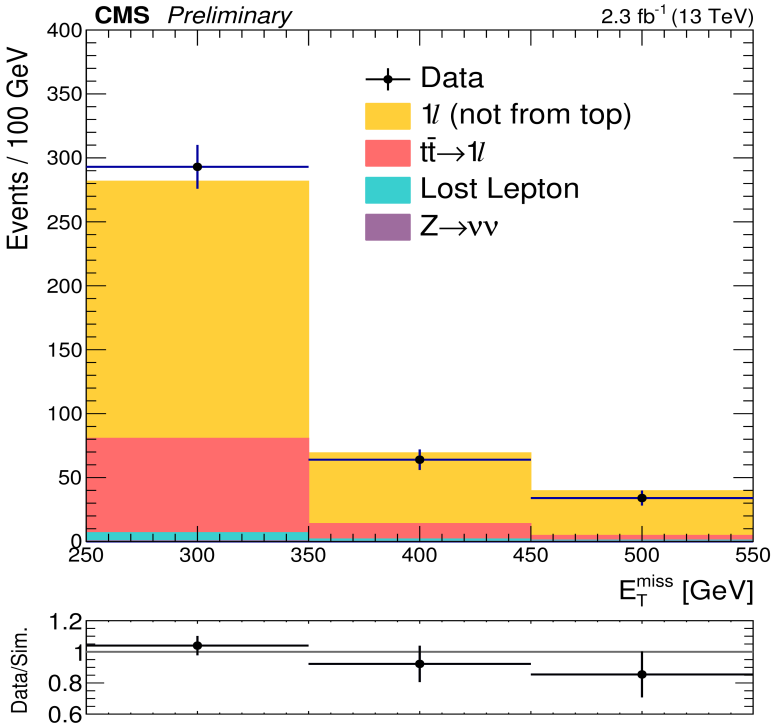


Targeted models	N_{Jets}	M_{T2}^W [GeV]	t_{mod}	E_T^{miss} [GeV]		
Low ΔM	≥ 4	≤ 200		250–325	> 325	
High ΔM	≥ 4	> 200		250–350	350–450	> 450
Boosted High ΔM	$= 3$	> 200		250–350	> 350	
Compressed $\tilde{\chi}_1^\pm - \tilde{\chi}_1^0$	$= 2$		> 6.4	250–350	> 350	

Background estimation

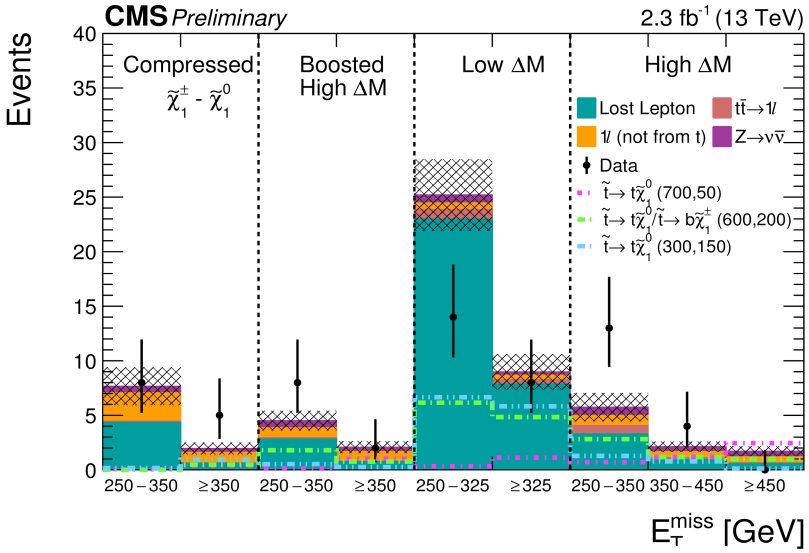
- Lost lepton:
  - Taken from 2 leptons control region
- W+jets:
  - Estimated from 0 b-tag control region
- Rare backgrounds
  - From Monte Carlo simulation

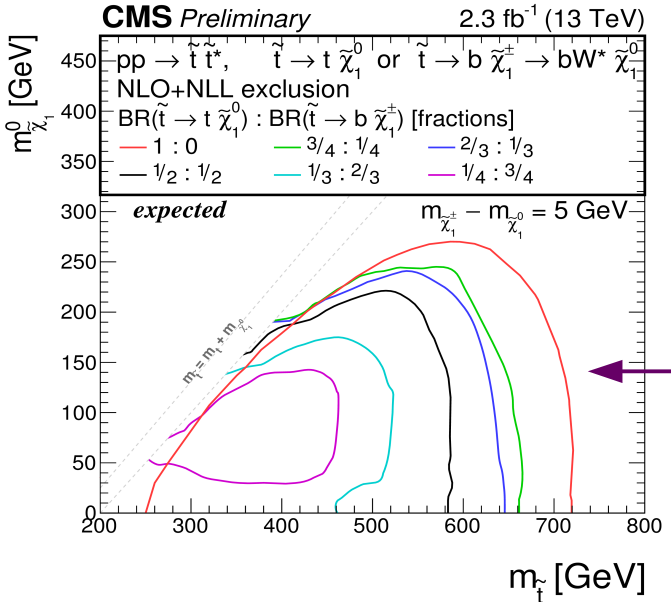


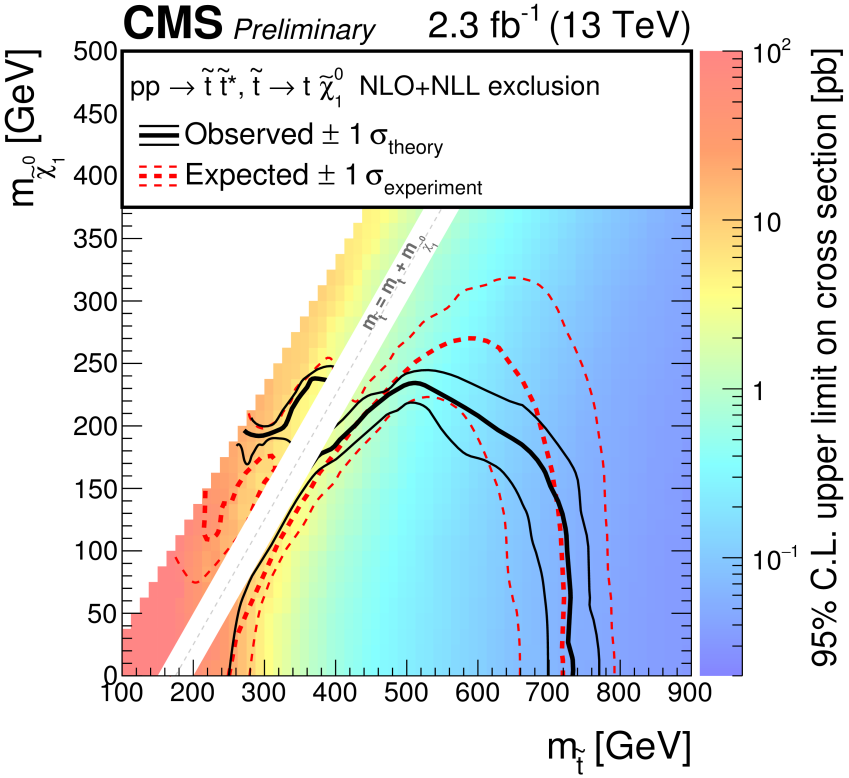


Results

- No significant excess observed in the 2.3fb^{-1} of data:





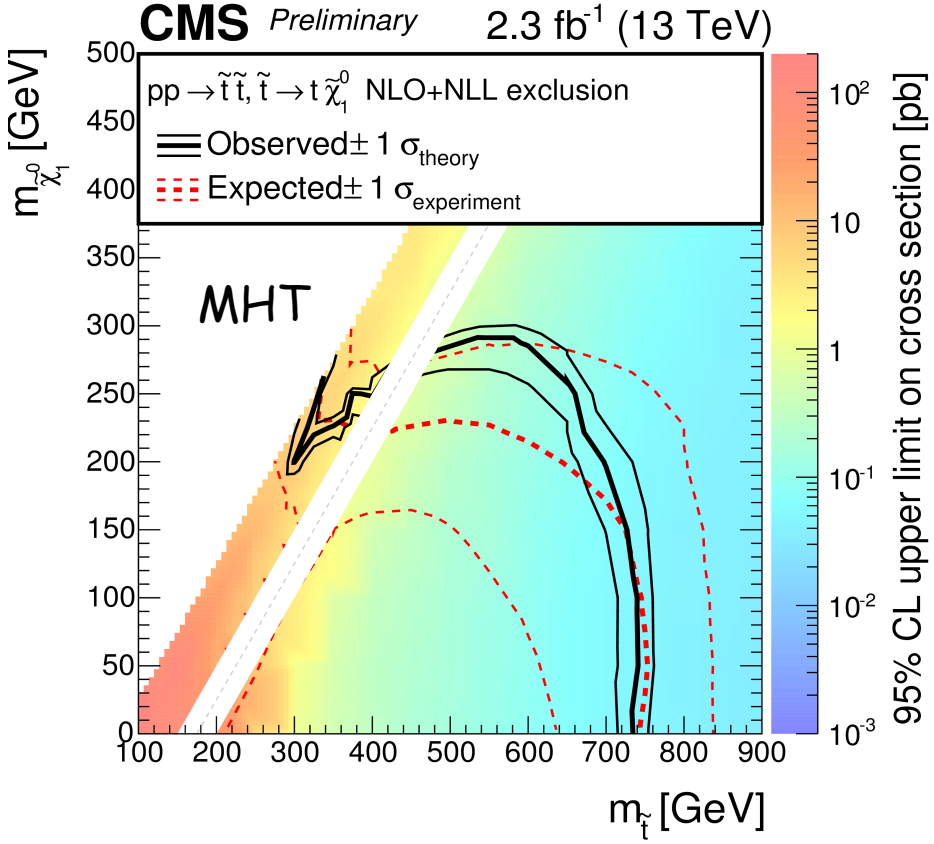


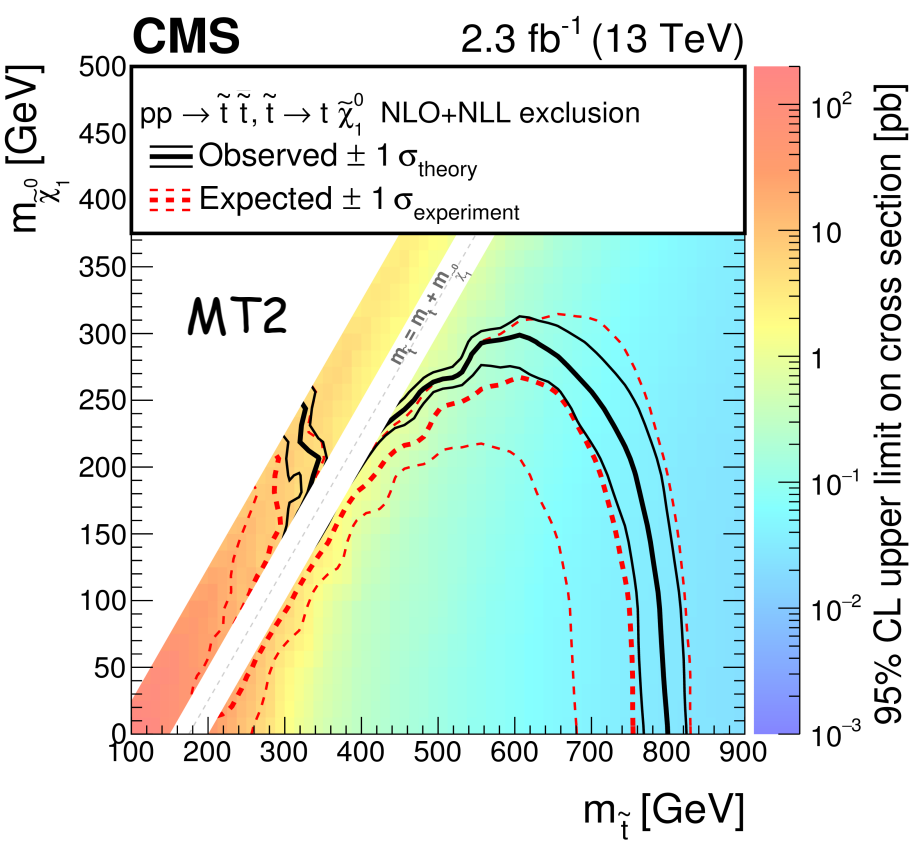
- Limits set for different BFs, assuming:

$$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}^0} + 5 \text{ GeV}$$

Inclusive 0-lepton analyses

- Inclusive analyses described in details in dedicated talks:
  - MHT analysis (SUS-15-002): talk from Kevin Pedro
  - MT2 analysis (SUS-15-003): talk from Mario Masciovecchio

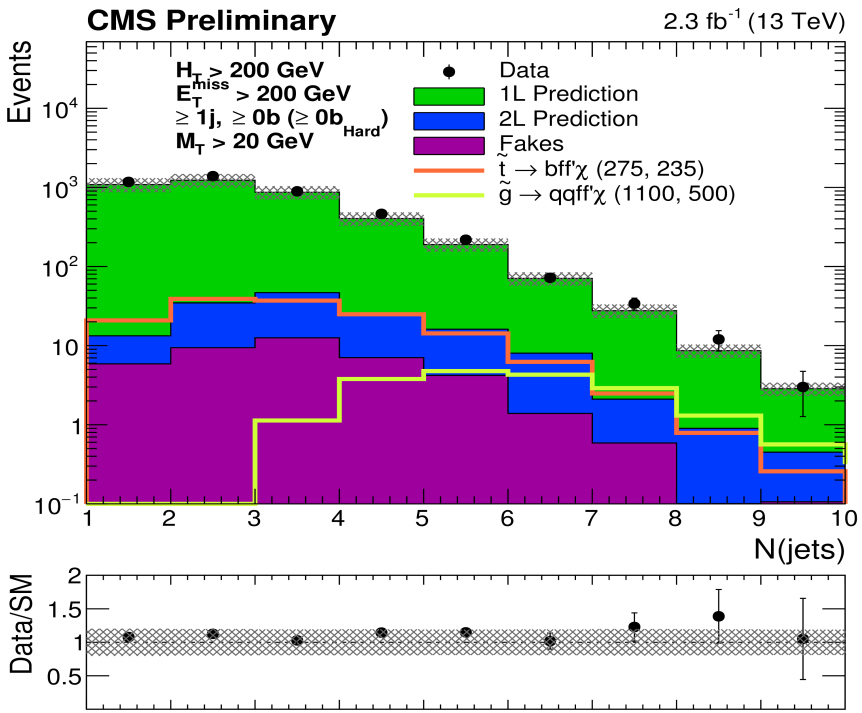


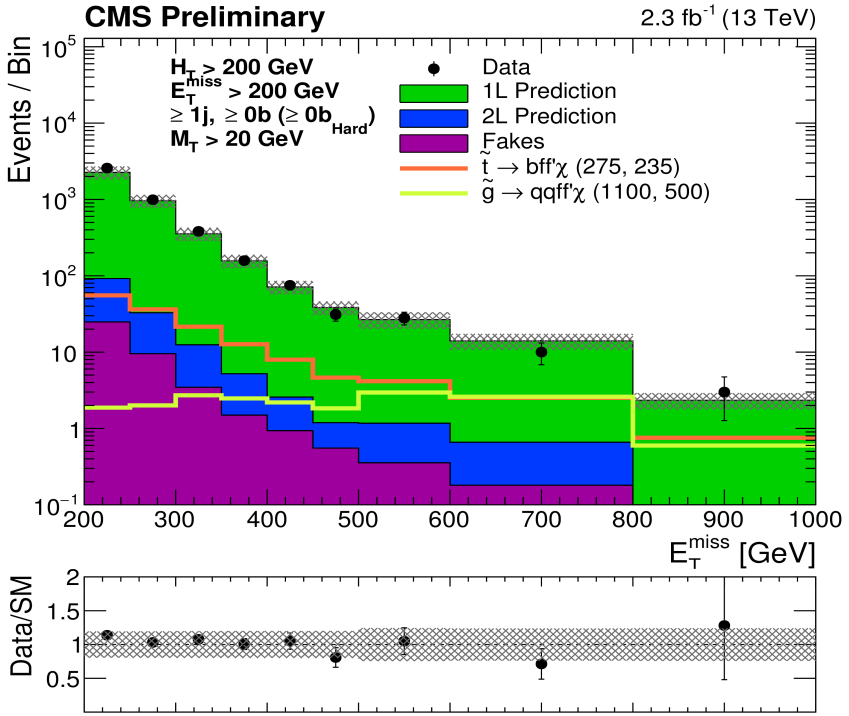


Search with 1 soft lepton

SUS-16-011

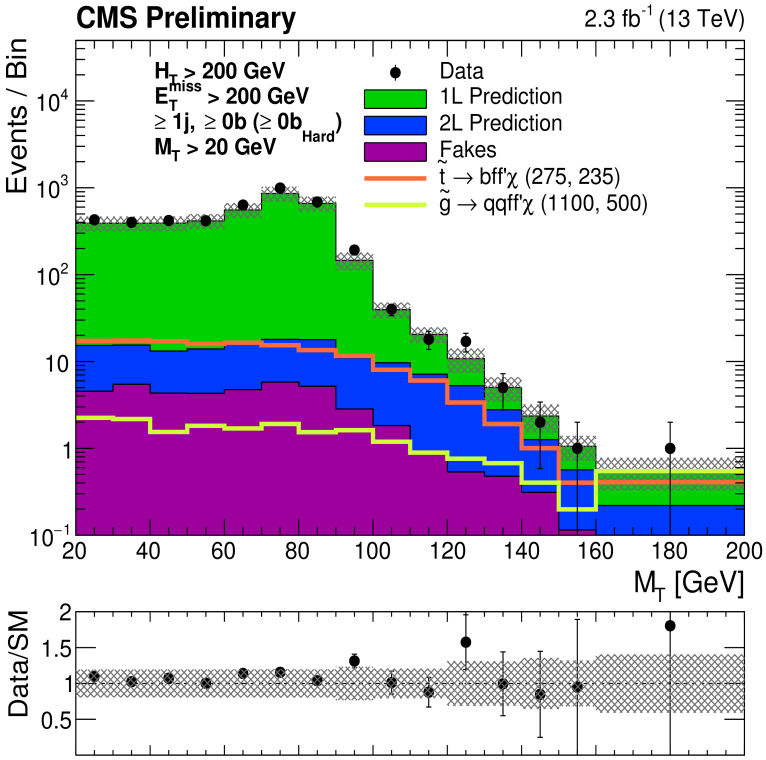
- Selection : exactly one soft lepton (e or μ) : 5 < p_T < 20 GeV
- At least 1 jet, HT>200 GeV, MET>200 GeV, |MET-HT|<0.5 MET, mT> 20 GeV
- Contribution from fakes is small, excellent modeling of all kinematic distributions.
- Builds on experience with low p_T leptons as vetoes for 0-lepton searches.





Backgrounds estimation

- 1 lepton background:
- W and top (1 lepton) with 1 soft lepton, hard neutrino
- 1 lepton control region: high p_T lepton, soft MET
- Uncertainties: W polarization, W/tt composition, lepton efficiency

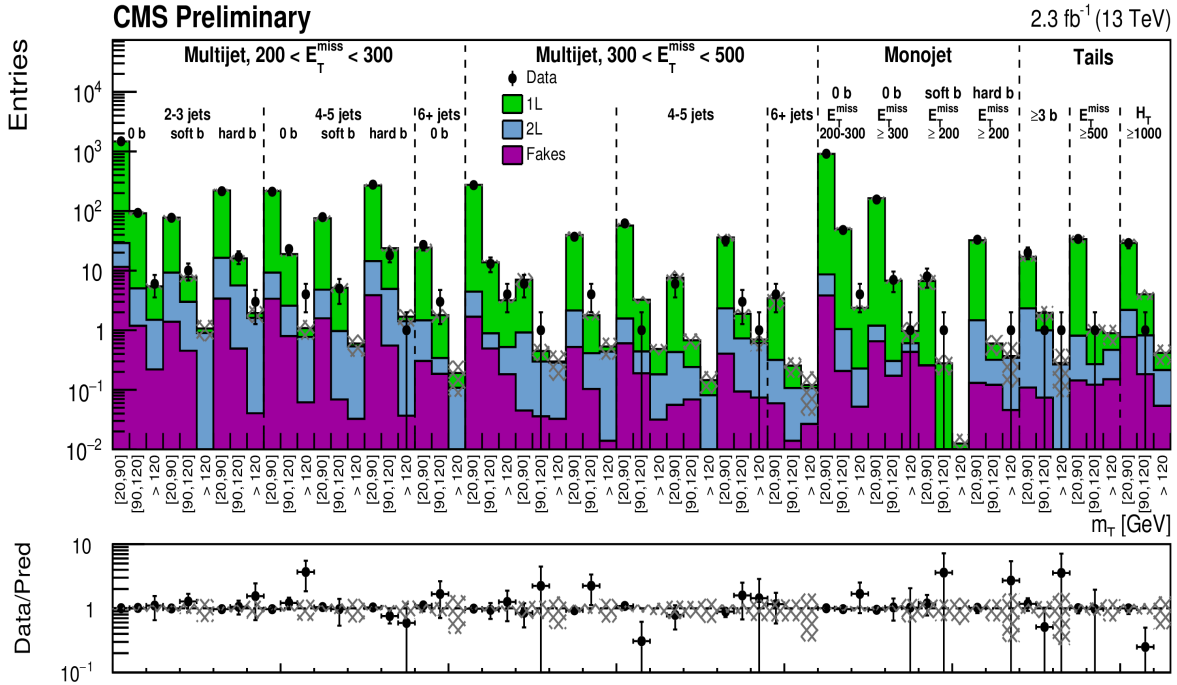


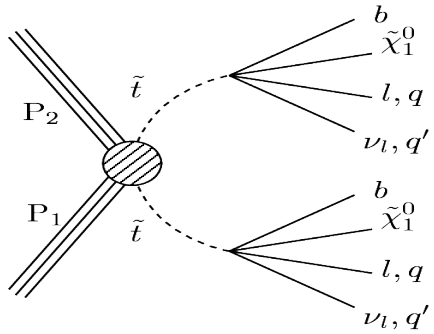
- 2 leptons background:
- Top (2 lepton)
- Significant background in MT tail
- Control region: SR + 1 extra lepton
- Uncertainties: lepton efficiency, acceptance

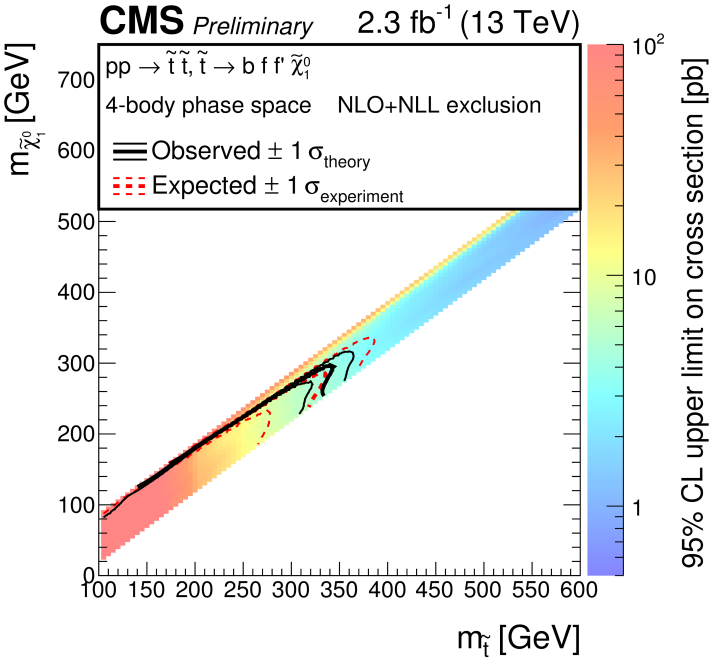
- Fakes:
- Small after tight ID/ISO and large MET
- Use MC for MT<120 GeV, fake rate method above

Results of 1 soft lepton analysis

- No significant excess observed in the 2.3fb^{-1} of data:

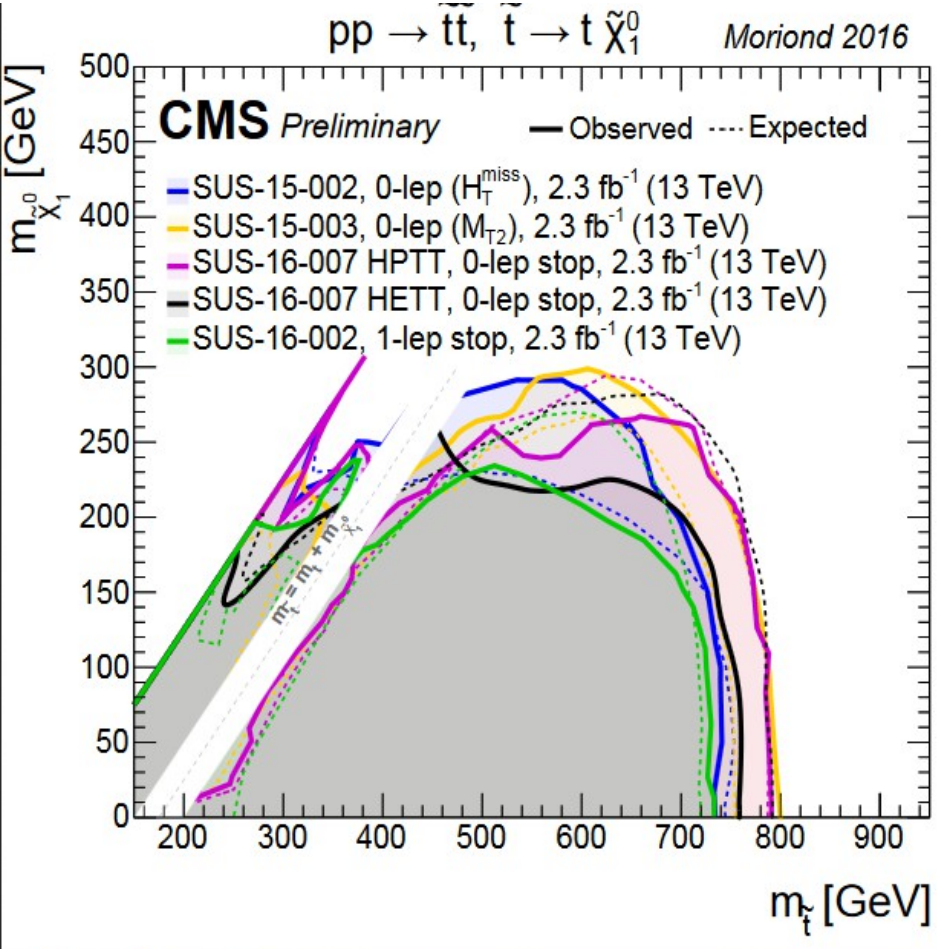


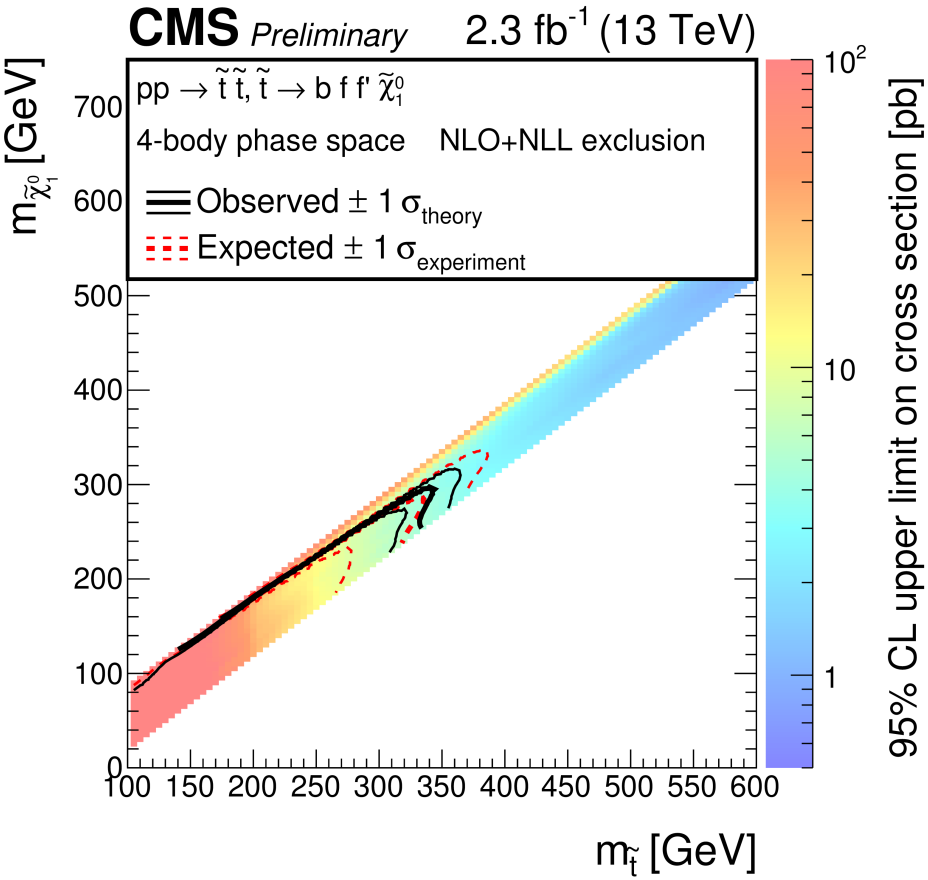




Summary of direct stop results

- No significant excess observed so far...



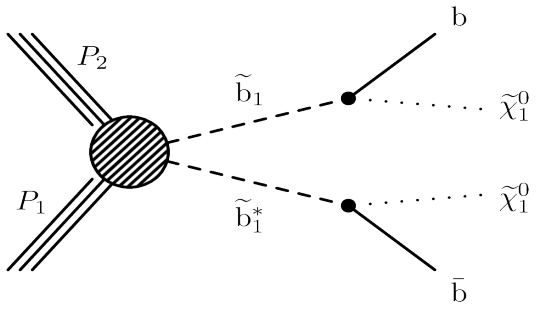


Direct sbottom production

- Dedicated analysis
- Selection:

SUS-16-001

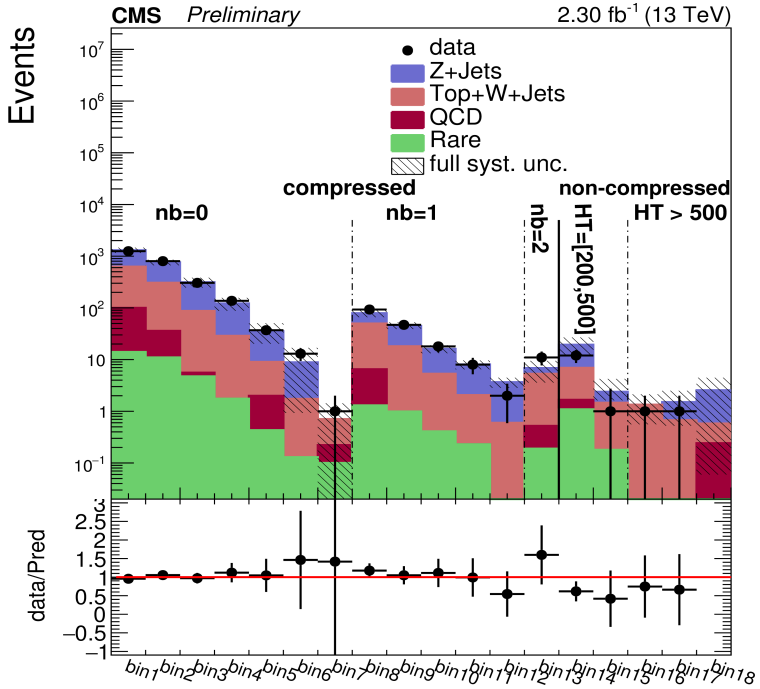
N_{jets}	[2,3]
1st-jet p_{T}	> 100 GeV
2nd-jet p_{T}	> 75 GeV
Veto fourth jet	$p_{\text{T}} > 50$ GeV
Lepton and isolated track veto	$p_{\text{T}} > 10$ GeV
b jet	1st and 2nd-jet are b jets
$E_{\text{T}}^{\text{miss}}$	> 250 GeV
$\Delta\phi(\text{j}_{123}, E_{\text{T}}^{\text{miss}})$	> 0.4
$\Delta\phi(\text{j}_1, E_{\text{T}}^{\text{miss}})$	-
$\min M_{\text{T}}(\text{j}, E_{\text{T}}^{\text{miss}})$	> 250 GeV
H_{T}	> 200 GeV
m_{CT}	> 250 GeV

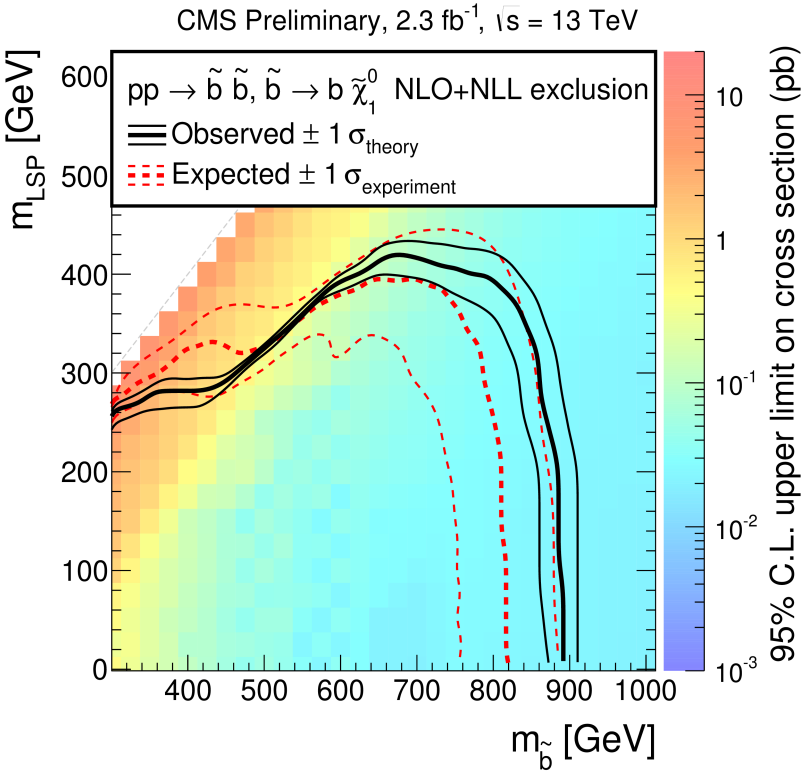


- Backgrounds estimation:
  - Lost lepton background
    - From single e/μ control sample (transfer factor)
  - $Z \to \nu\nu$
    - From $Z \to \mu\mu$ sample
  - QCD multijets
    - From inverted deltaPhi and low MET control region

Direct sbottom results

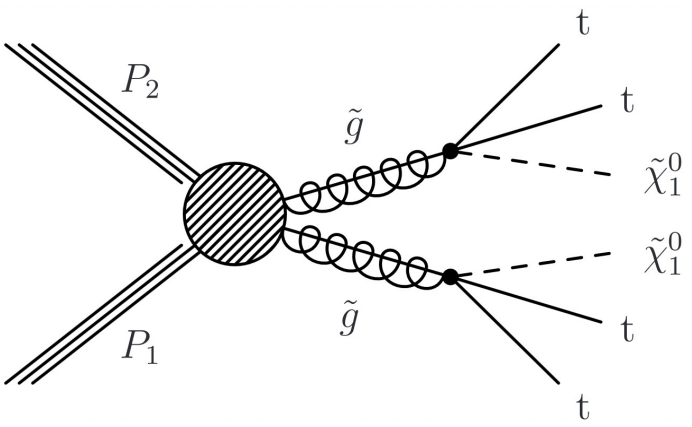
- No significant excess observed in the 2.3fb^{-1} of data:



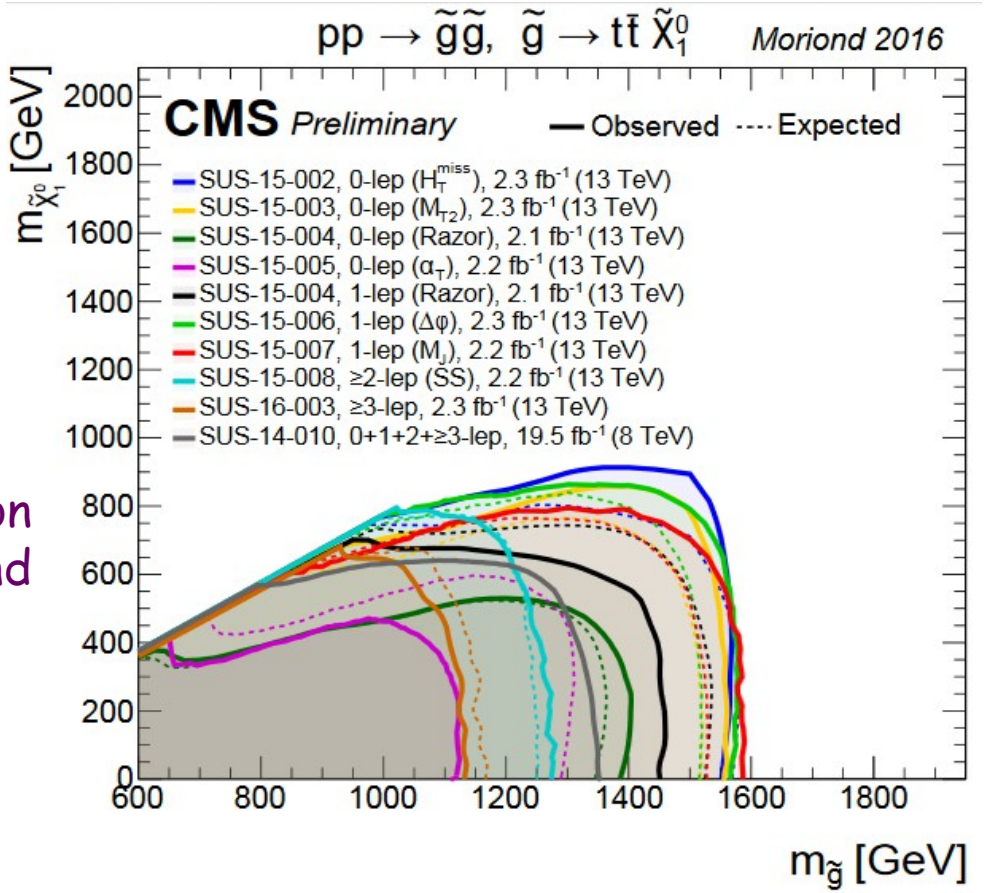


Gluino mediated production

- Gluino can decay via a virtual stop or a virtual sbottom
- Gluino pairs decaying to 4 tops :



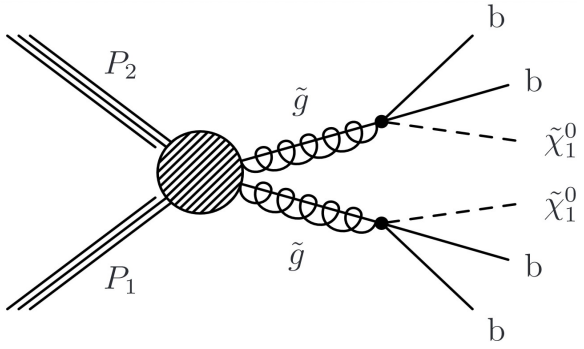
- Interpretation made by 0-lepton inclusive analyses, 1 lepton analyses and multilepton analyses, cf talks from:
  - Javier Duarte (razor)
  - Mario Masciovecchio (MT2)
  - Kevin Pedro (MHT)
  - Tai Sakuma (alphaT)
  - Claudia Seitz (single lepton)
  - Jan Hoss (multilepton)



- Gluino masses excluded up to almost 1.6 TeV for m(LSP)=0 GeV

Gluino pairs to 4 bottoms

- Gluino pairs decay to 4 b-quarks:



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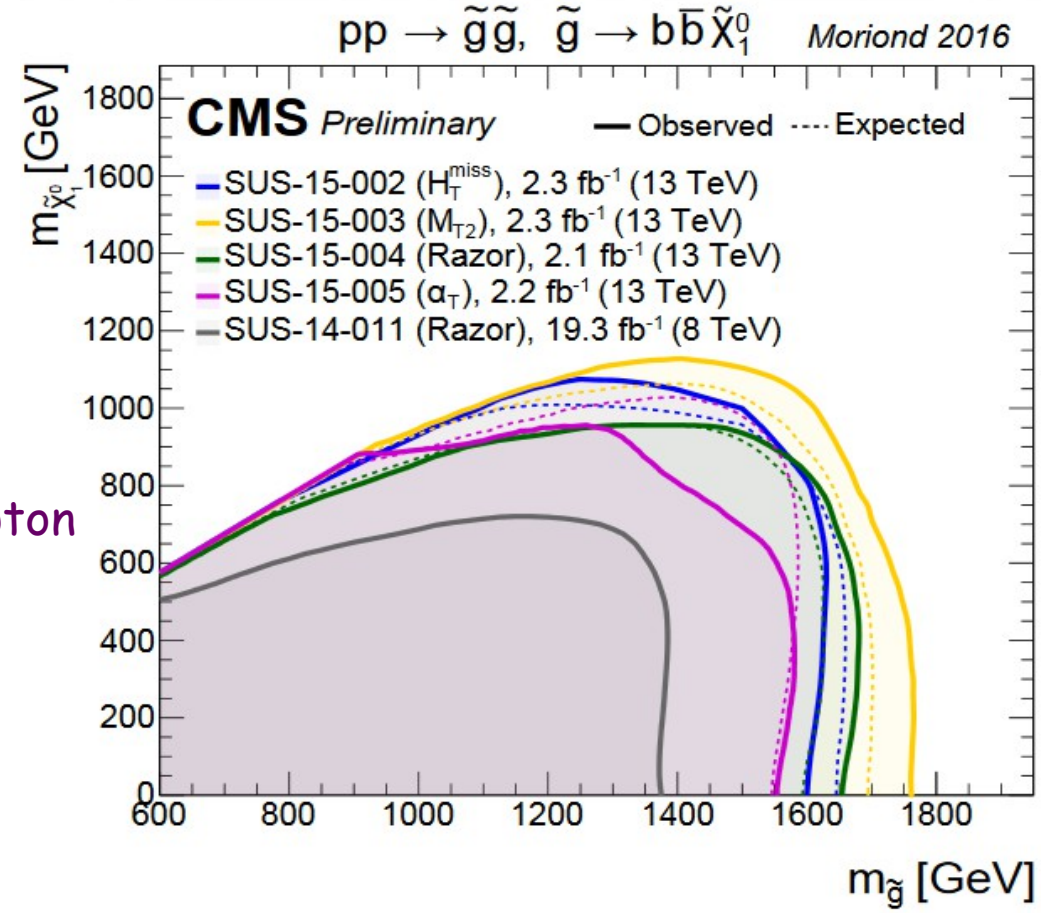
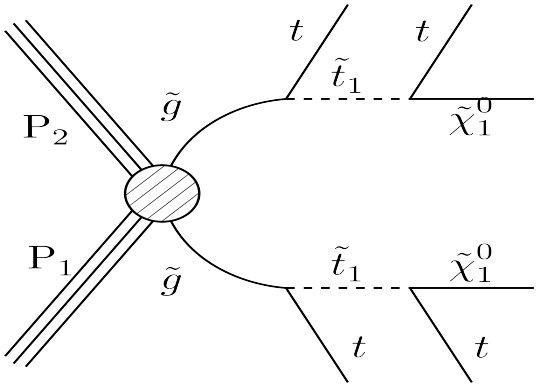


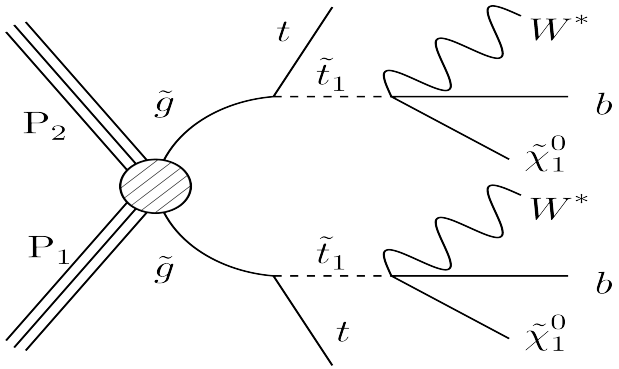
- Gluino masses excluded up to almost 1.8 TeV for m(LSP)=0 GeV

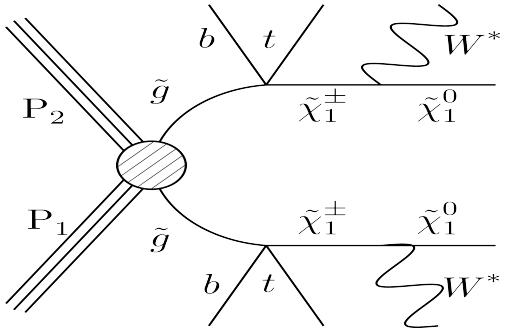
More results

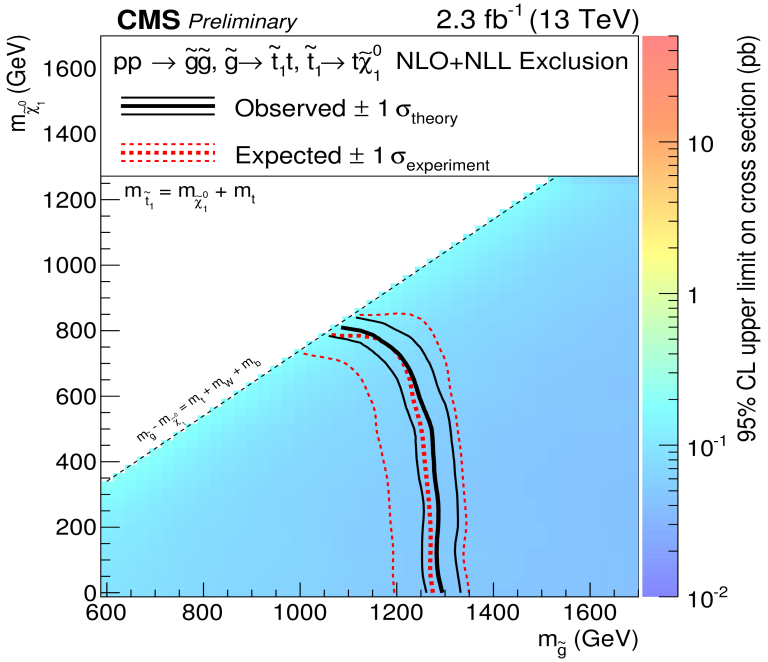
- T5ttttDM175, T5ttttdegen, T1ttbb, T5ttcc, T6ttWW….

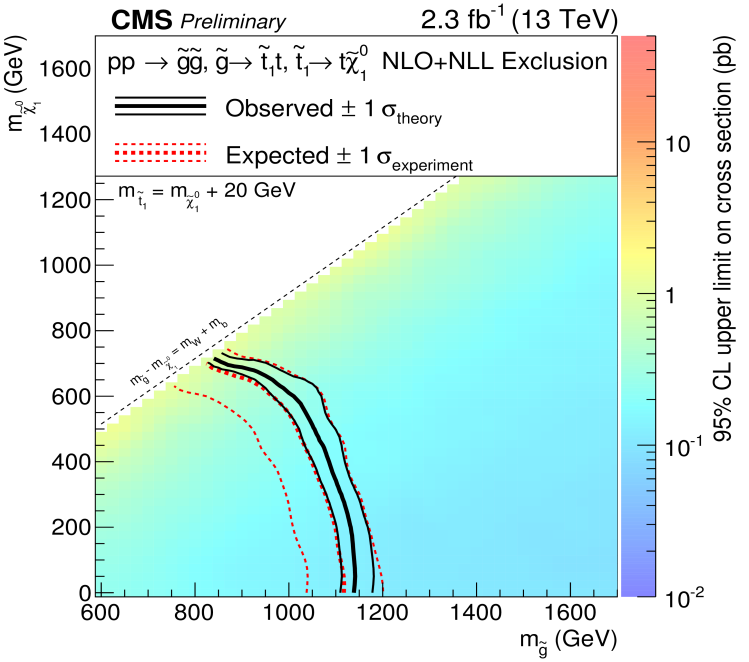
SUS-16-004





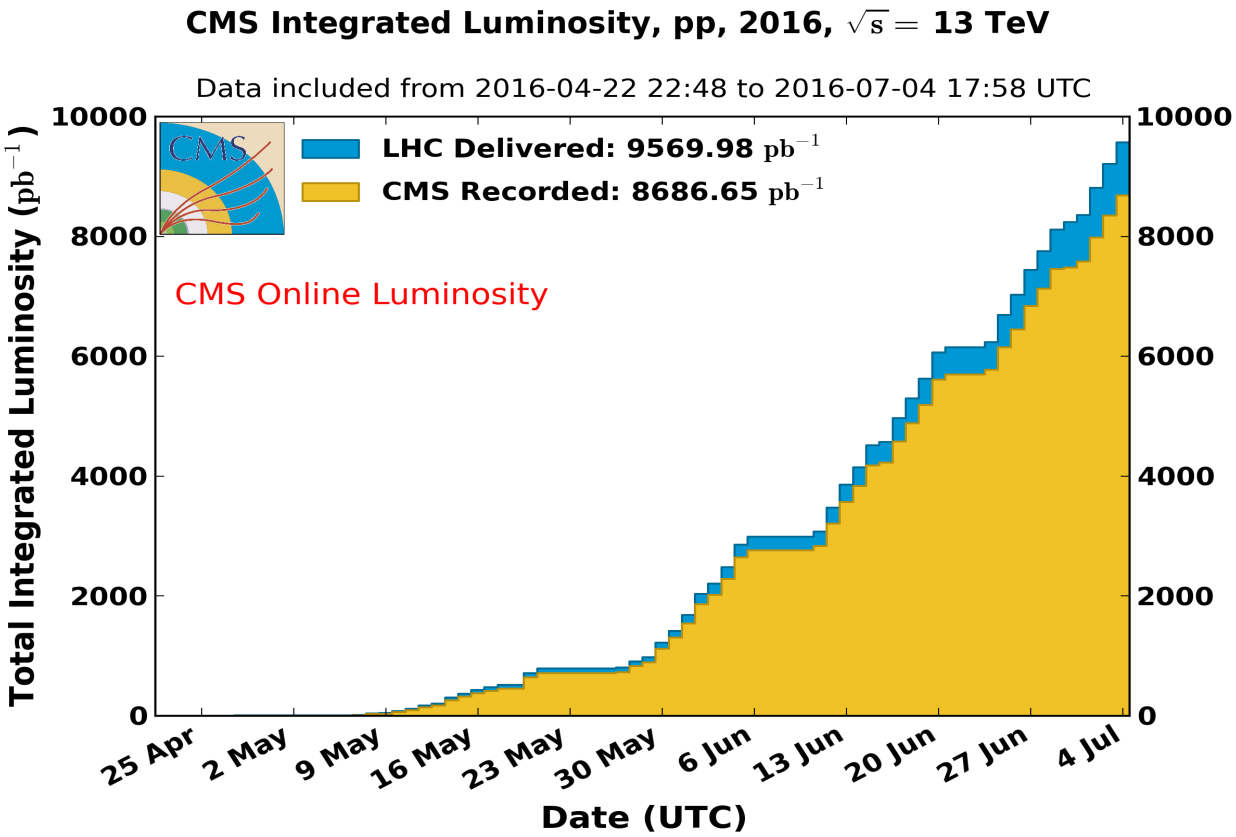






Conclusion

- Large number of CMS analyses covering stop and sbottom searches for direct or gluino mediated production.
- No excess observed, limits have been set for Simplified Models.
- Exciting months ahead, stay tuned: high luminosity expected for this year!
- ICHEP 3rd generation talk by Nadja Strobbe on Aug 3rd.



BACK UP

SLIDES

Definition of 1 lepton variables

$$M_{\mathrm{T2}}^{\mathrm{W}} = \min\{m_y, \text{ consistent with: } [p_1^2 = 0,\ (p_1 + p_\ell)^2 = p_2^2 = M_{\mathrm{W}},\ \vec{p}_{\mathrm{T}}^{\,1} + \vec{p}_{\mathrm{T}}^{\,2} = \vec{E}_{\mathrm{T}}^{\mathrm{miss}},\ (p_1 + p_\ell + p_{b_1})^2 = (p_2 + p_{b_2})^2 = m_y^2]\}, \quad (3)$$

where m_y is the fitted mother particle mass, and p_1, p_2, b_1, and b_2, are the decay components.

$$t_{\mathrm{mod}} = \ln(\min S) \text{ with } S(\vec{p}_{\mathrm{W}}, p_{\nu,z}) = \frac{(m_{\mathrm{W}}^2 - (p_\nu + p_\ell)^2)^2}{a_{\mathrm{W}}^4} + \frac{(m_t^2 - (p_b + p_{\mathrm{W}})^2)^2}{a_t^4}. \quad (4)$$

We select events with $t_{\mathrm{mod}} > 6.4$. The definition of topness used in this analysis is modified from the one originally proposed in [33]; namely, the terms corresponding to the leptonic top quark decay and the center-of-mass energy are dropped. The reason is that in events with low jet multiplicity the second b-jet is often not identified. In these cases, the discriminating power of the topness variable is reduced when a light-flavor jet is used instead in the calculation. Modified topness as presented here is more robust against such effects and provides better performance in these search region as compared to $M_{\mathrm{T2}}^{\mathrm{W}}$. The calculation of modified topness in this analysis uses resolution parameters $a_{\mathrm{W}} = 5\,\mathrm{GeV}$ and $a_t = 15\,\mathrm{GeV}$. The distribution of modified topness for events with two jets is shown in Fig. 3 (right).