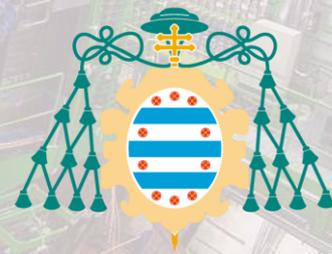


CMS searches for supersymmetry in leptonic and fully hadronic final states

Ignacio Suárez Andrés
on behalf of the **CMS Collaboration**

**25th International Workshop on Deep Inelastic Scattering
and Related Topics (DIS2017)**

5th April, 2017
Birmingham, UK



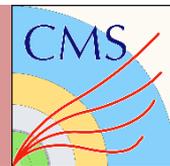
Universidad de Oviedo
Universidá d'Uviéu
University of Oviedo



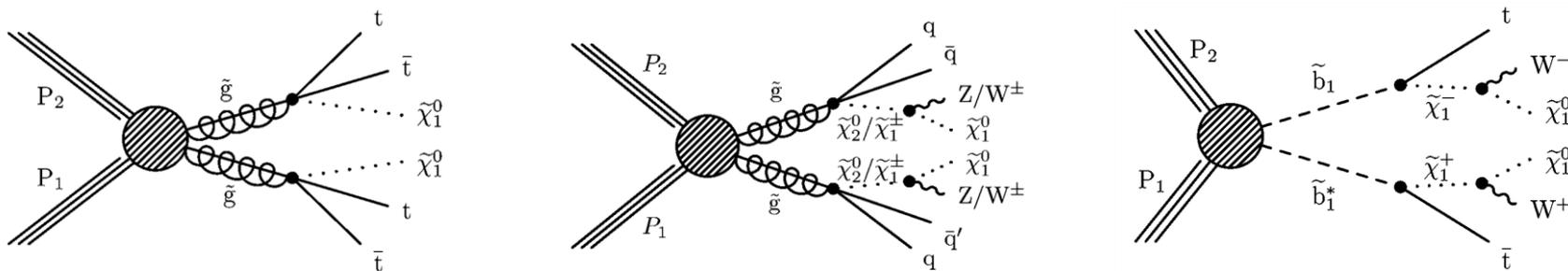
CMS

The CMS logo, featuring the letters 'CMS' in a blue serif font, with a stylized red and orange graphic below it.

Introduction



- For decades, supersymmetry (SUSY) models have remained popular candidates for new physics beyond the Standard Model, with a colorful array of final states to study.
- An overview of the latest searches from the CMS Collaboration guided by models for **strong SUSY** production with **leptonic and fully hadronic final states** will be presented here.



- ✓ Dedicated third-generation squark searches covered by **Marketa Jansova**.
- ✓ Electroweak SUSY production searches covered by **Ece Asilar**.

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS>

PARTICLES

SPARTICLES

Quarks

Leptons

Squarks

Sleptons

3rd generation



2nd generation



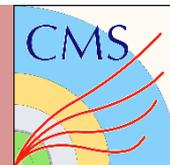
1st generation



Fully hadronic searches



Jets with H_T^{miss}



Selection:

≥ 2 jets

$$H_T = \sum_{\text{jet}, |\eta| < 2.4} p_T^{\text{jet}} > 300 \text{ GeV}$$

$$H_T^{\text{miss}} = \left| -\sum_{\text{jet}, |\eta| < 5} \vec{p}_T^{\text{jet}} \right| > 300 \text{ GeV}$$

$$\Delta\phi(\vec{H}_T^{\text{miss}}, j_{1,2}) > 0.5, \Delta\phi(\vec{H}_T^{\text{miss}}, j_{3,4}) > 0.3$$

Veto on leptons and low- M_T isolated tracks

Categorization based on:

N_{jets}

H_T

$N_{\text{b jets}}$

H_T^{miss}

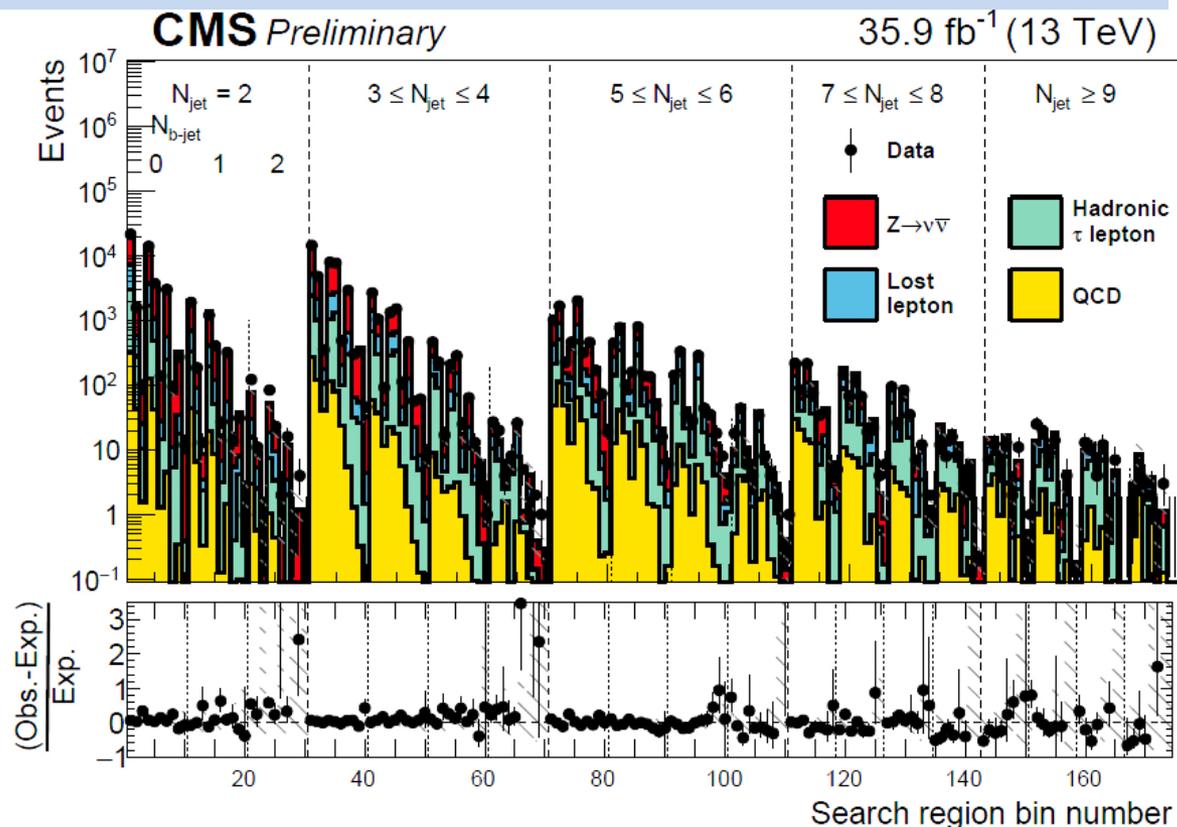
Dominant background:

$Z \rightarrow \nu\bar{\nu}$

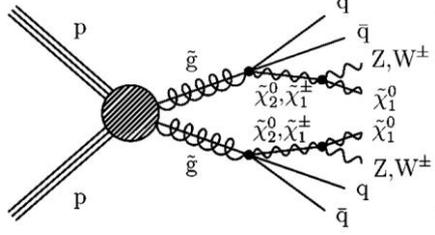
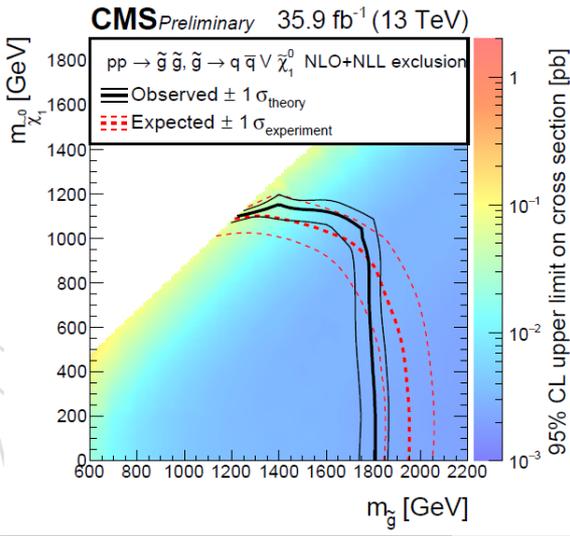
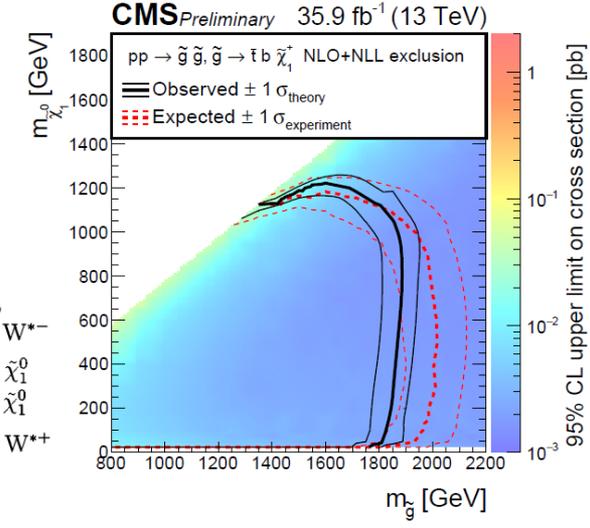
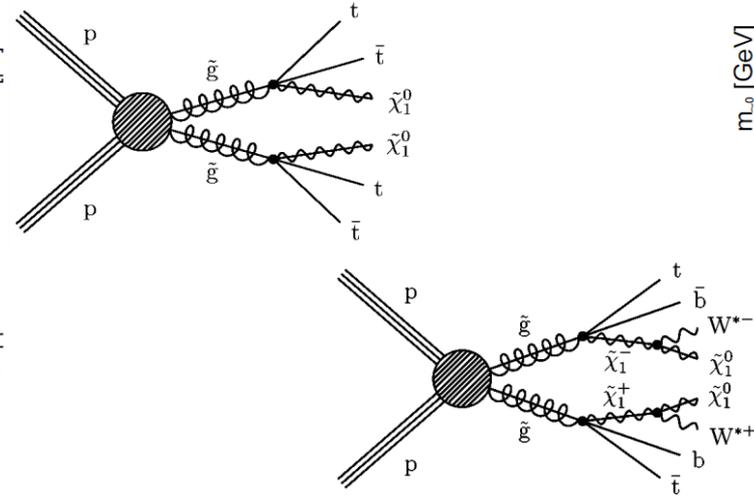
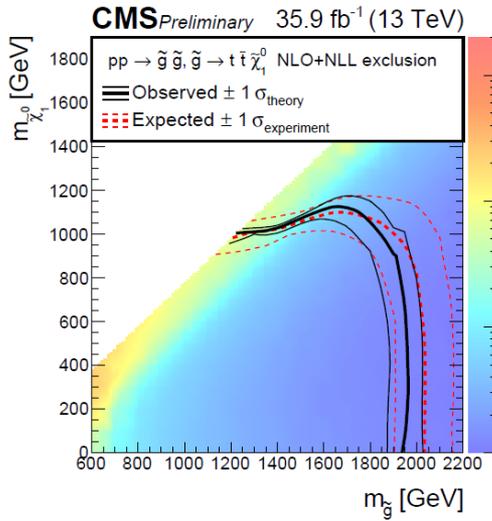
Lost e/μ

Hadronic τ

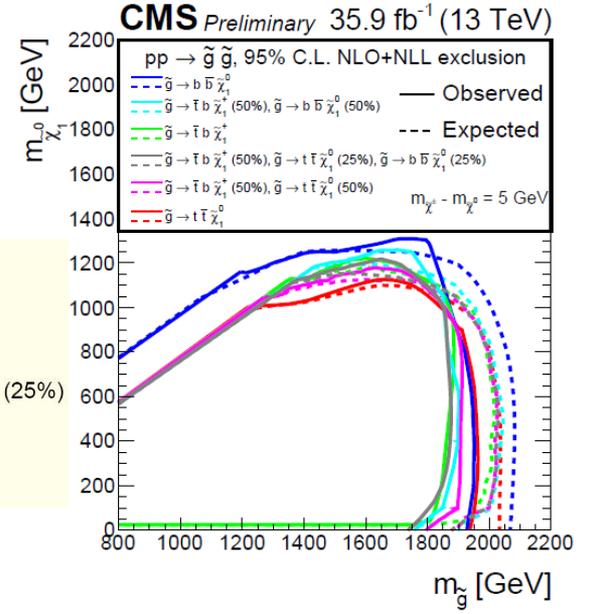
CMS-PAS-SUS-16-033



Jets with H_T^{miss}

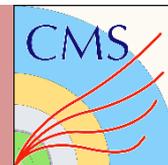


- Mixed models**
- $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$
 - $\tilde{g} \rightarrow \bar{t}b\tilde{\chi}_1^+$ (50%), $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ (50%)
 - $\tilde{g} \rightarrow \bar{t}b\tilde{\chi}_1^+$
 - $\tilde{g} \rightarrow \bar{t}b\tilde{\chi}_1^+$ (50%), $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ (25%), $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ (25%)
 - $\tilde{g} \rightarrow \bar{t}b\tilde{\chi}_1^+$ (50%), $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ (50%)
 - $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$



CMS-PAS-SUS-16-033

Jets with M_{T2}



Selection:

≥ 1 jets (M_{T2} used only if $N_{\text{jets}} \geq 2$)

$p_T^{\text{miss}} > 250$ (30) GeV (if $H_T > 1000$ GeV)

$M_{T2} > 200$ (400) GeV (if $H_T > 1500$ GeV)

$$|\vec{p}_T^{\text{miss}} - \vec{H}_T^{\text{miss}}|/p_T^{\text{miss}} < 0.5$$

$$\Delta\phi(\vec{p}_T^{\text{miss}}, j_{1,2,3,4}) > 0.3$$

Veto on leptons and low- M_T isolated tracks

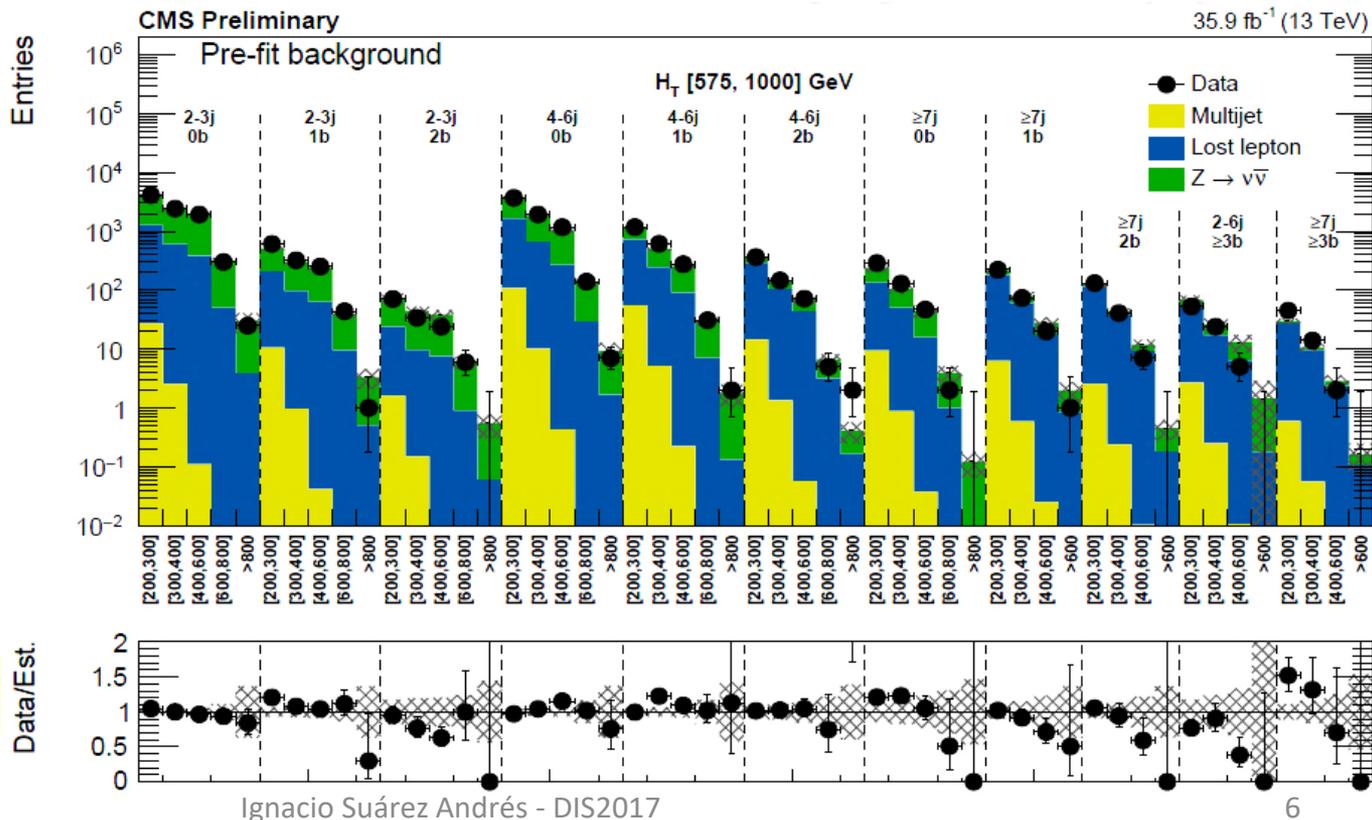
$$M_{T2} = \min_{\vec{p}_T^{\text{miss}X(1)} + \vec{p}_T^{\text{miss}X(2)} = \vec{p}_T^{\text{miss}}} \left[\max \left(M_T^{(1)}, M_T^{(2)} \right) \right] \text{ Jets clustered into two pseudojets}$$

Categorization based on:

N_{jets} H_T
 N_{bjets} M_{T2}

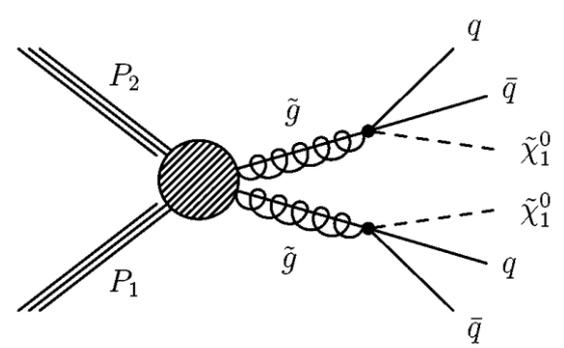
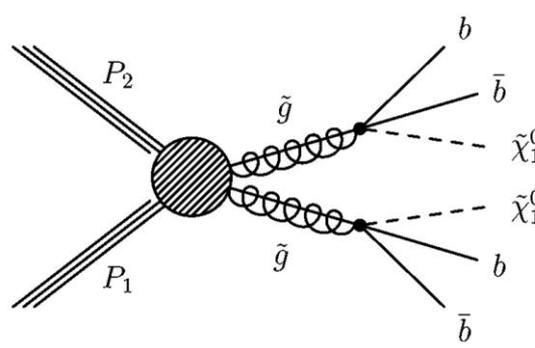
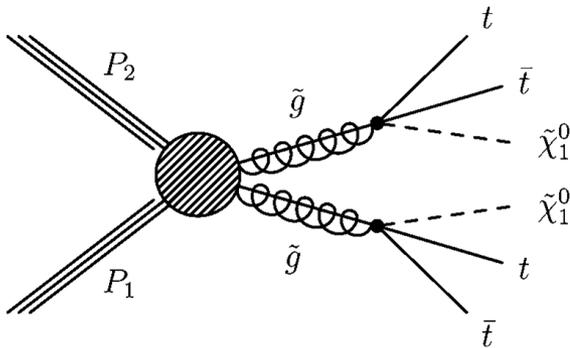
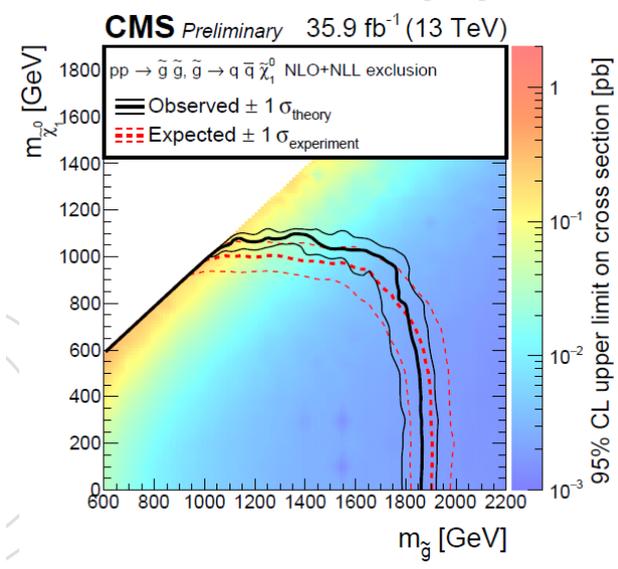
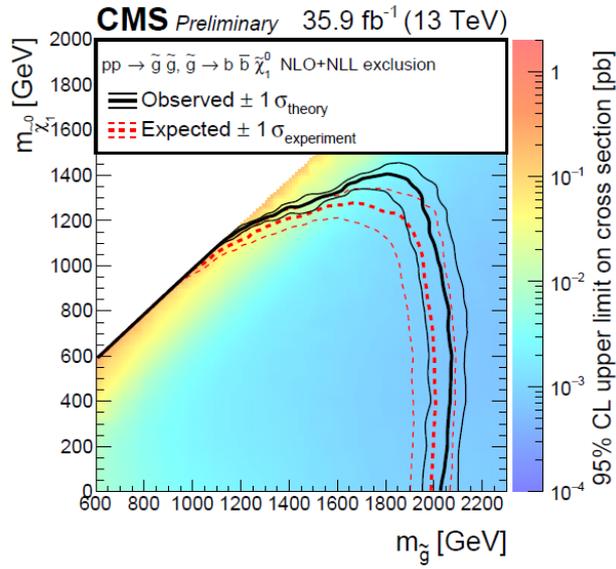
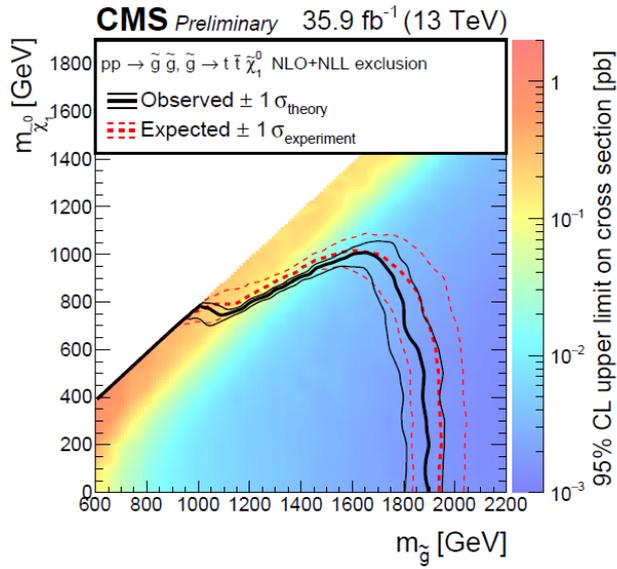
Dominant background:

$Z \rightarrow \nu\bar{\nu}$
 Lost e/μ



CMS-PAS-SUS-16-036

Jets with M_{T2}



CMS-PAS-SUS-16-036

PARTICLES

SPARTICLES

Quarks

Leptons

Squarks

Sleptons

3rd generation



2nd generation



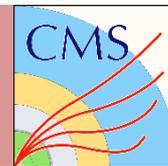
1st generation



Leptonic searches



1 lepton with M_J



Selection:

1 lepton, ≥ 6 jets, ≥ 1 b jet

$p_T^{\text{miss}} > 200$ GeV

$H_T + p_T^\ell > 500$ GeV

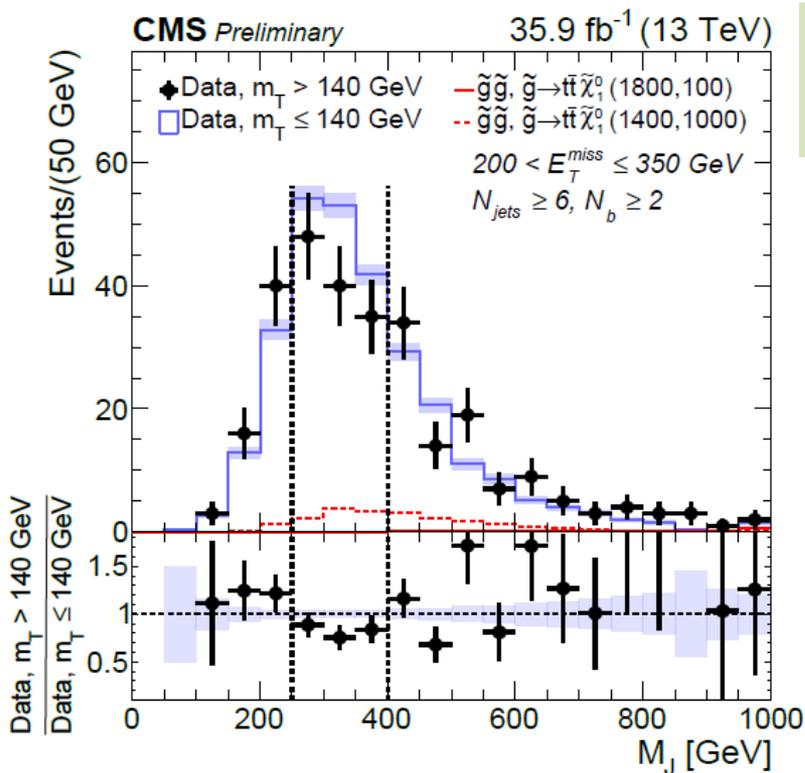
$M_T > 140$ GeV

$M_J = \sum_{\text{large-R jet}} m_j > 400$ GeV

Veto on low- M_T isolated tracks

Dominant background:

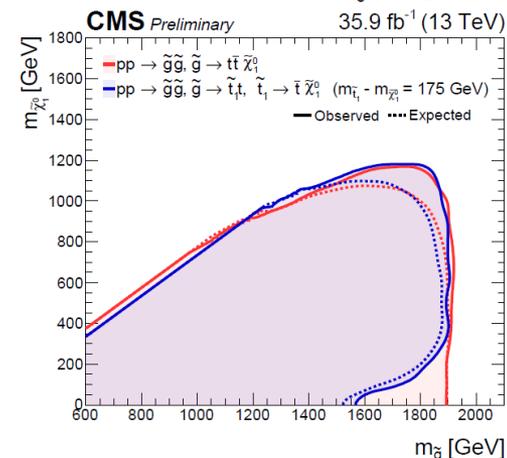
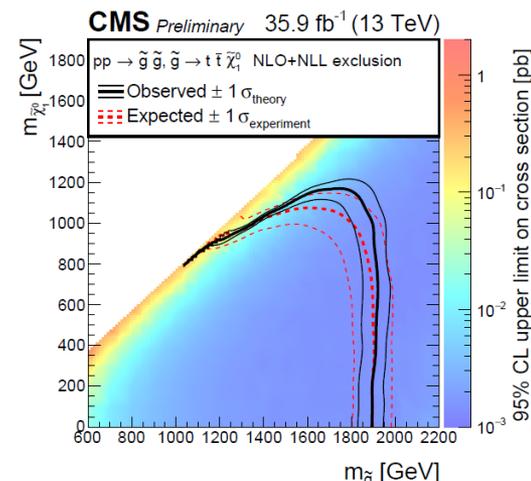
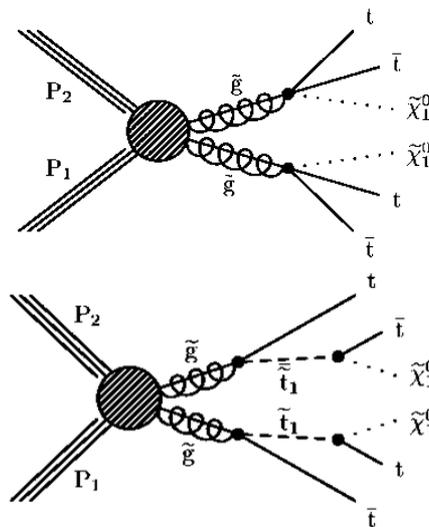
$t\bar{t}$, mostly dileptonic with a lost lepton



Categorization based on:

N_{jets} $N_{\text{b jets}}$ p_T^{miss}

CMS-PAS-SUS-16-037



1 lepton with $\Delta\phi$



Selection:

1 lepton, ≥ 5 (6) jets (if ≥ 1 b jet)

$$p_T^{j1} > 80 \text{ GeV}$$

$$L_T = p_T^{\text{miss}} + p_T^\ell > 250 \text{ GeV}$$

$$H_T > 500 \text{ GeV}$$

$\Delta\phi(\vec{p}_T^\ell, \vec{p}_T^\ell + \vec{p}_T^{\text{miss}})$ minimum threshold dependent on $N_{\text{jets}}, N_{\text{b jets}}, L_T$

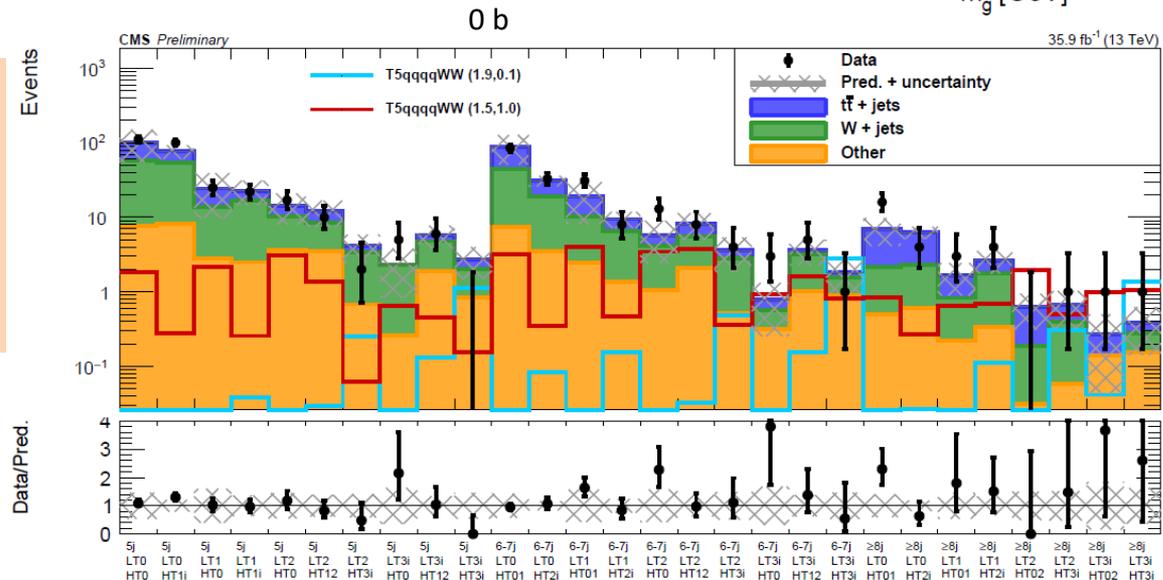
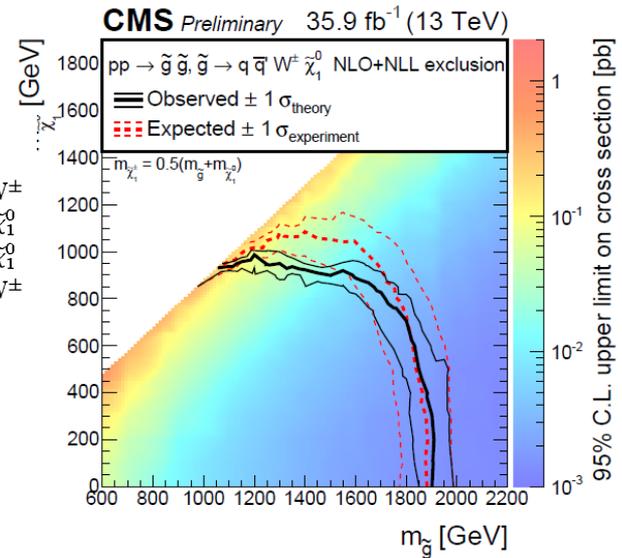
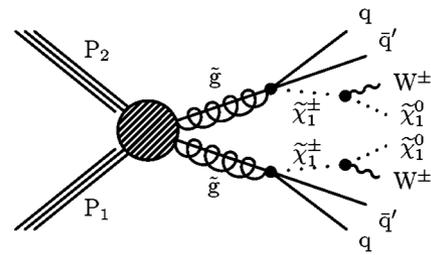
Veto on low- $M_{T2}^{\ell t}$ isolated tracks

Categorization based on:

$N_{\text{b jets}}$
 N_{jets}
 H_T
 L_T

Dominant background:
 $t\bar{t}$, mostly dileptonic with a lost lepton

CMS-PAS-SUS-16-042



1 lepton with $\Delta\phi$



Selection:

1 lepton, ≥ 5 (6) jets (if ≥ 1 b jet)

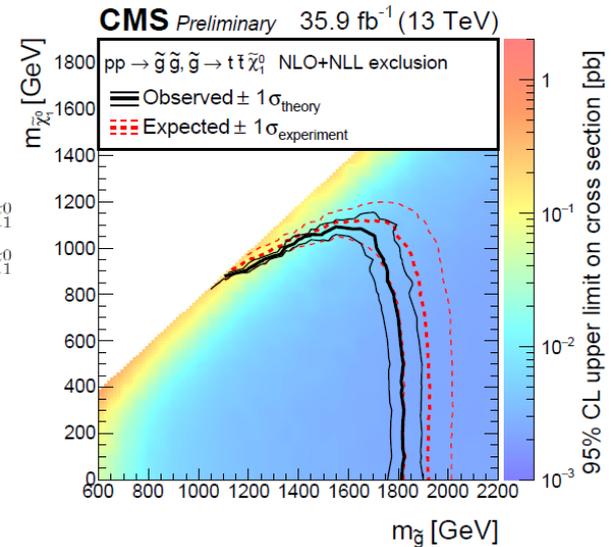
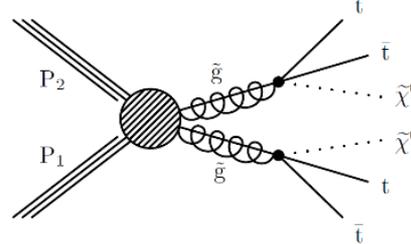
$$p_T^{j1} > 80 \text{ GeV}$$

$$L_T = p_T^{\text{miss}} + p_T^\ell > 250 \text{ GeV}$$

$$H_T > 500 \text{ GeV}$$

$\Delta\phi(\vec{p}_T^\ell, \vec{p}_T^\ell + \vec{p}_T^{\text{miss}})$ minimum threshold dependent on $N_{\text{jets}}, N_{\text{b jets}}, L_T$

Veto on low- $M_{T2}^{\ell t}$ isolated tracks

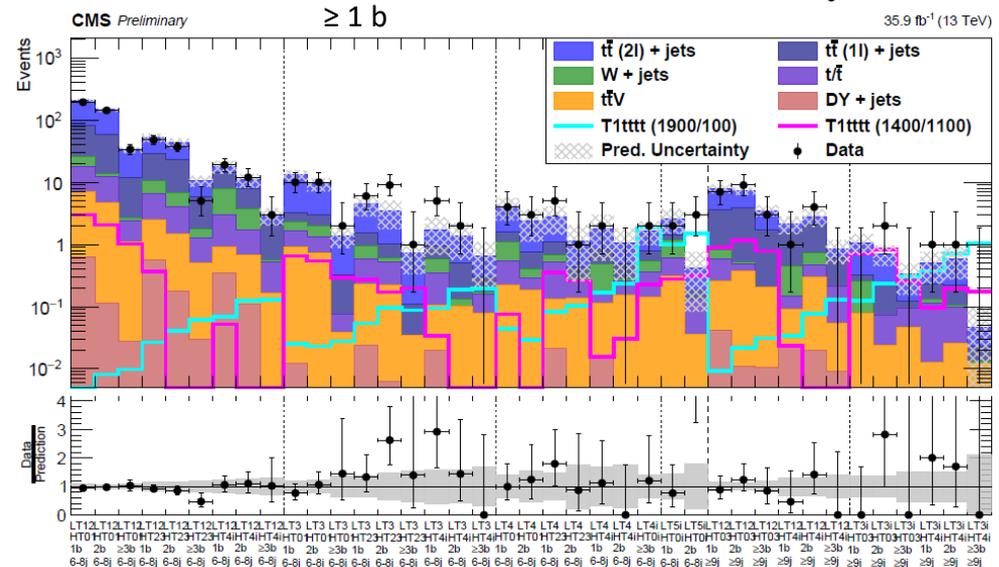


Categorization based on:

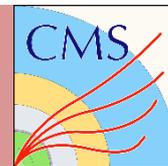
- $N_{\text{b jets}}$
- N_{jets}
- H_T
- L_T

Dominant background:
 $t\bar{t}$, mostly dileptonic with a lost lepton

CMS-PAS-SUS-16-042



Soft opposite sign dilepton



Selection:

2 leptons, opposite charge

$p_T^\ell \in [5, 30]$ GeV ($p_T^{\mu 2} \in [3.5, 30]$ GeV
in high p_T^{miss} \tilde{t} -like SRs)

≥ 1 jet, b jet veto ($p_T^b > 25$ GeV)

$p_T^{\text{miss}} > 125$ GeV

p_T^{miss} (muon subtracted) > 125 GeV

$H_T > 100$ GeV

$p_T^{\text{miss}}/H_T \in [0.6, 1.4]$

$m_{\ell\ell} > 4, < 50, \notin [9, 10.5]$ GeV

$m_{\tau\tau} \notin [0, 160]$ GeV

Dominant background:

Nonprompt or

misidentified leptons (W+jets)

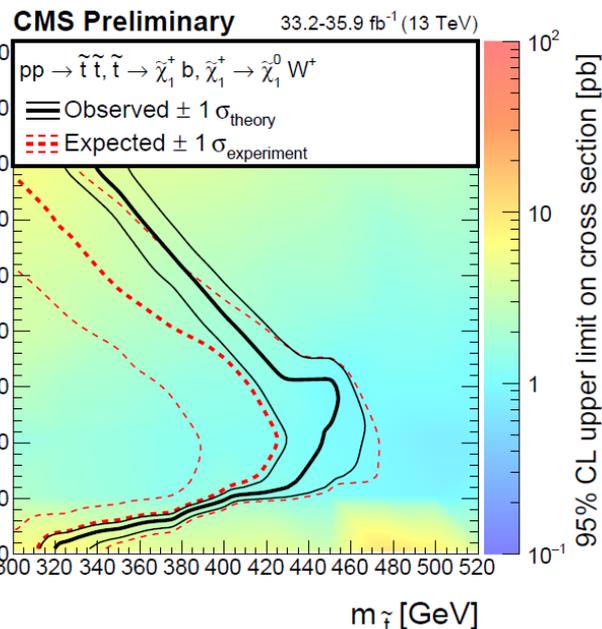
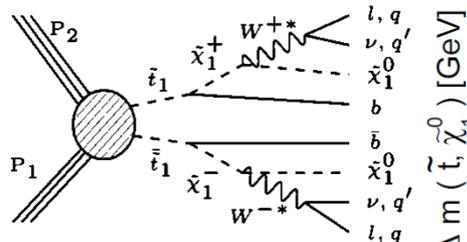
Dileptonic $t\bar{t}$

VV, $Z/\gamma^* \rightarrow \tau\tau$

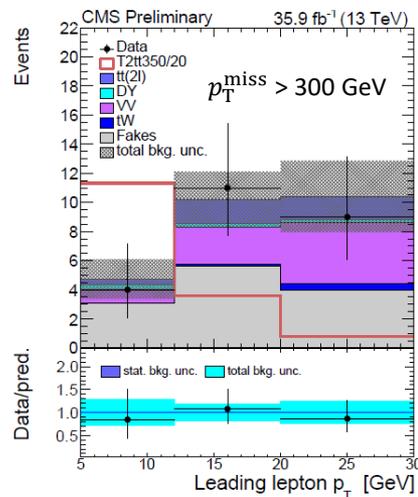
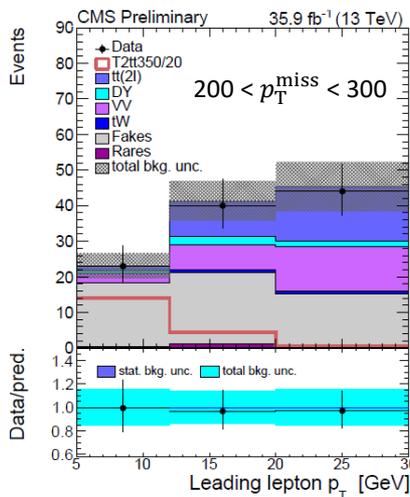
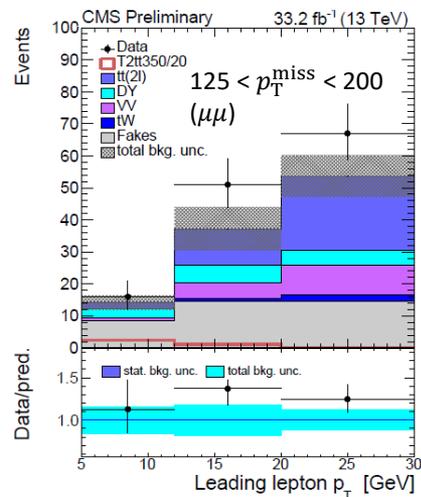
Categorization based on:

p_T^{miss}

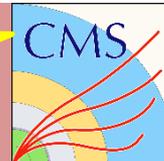
$p_T^{\ell 1}$



CMS-PAS-SUS-16-048



Opposite sign dilepton (on-Z)



Selection:

2 leptons, opposite charge

≥ 2 jets

$86 < m_{\ell\ell} < 96$ GeV

$p_T^{\text{miss}} > 100$ GeV

$\Delta\phi(\vec{p}_T^{\text{miss}}, j_{1,2}) > 0.4$

$M_{T2}^{\ell\ell} > 80$ (100) GeV (if $N_{b\text{ jets}} \geq 1$)

H_T dependent on N_{jets} and $N_{b\text{ jets}}$

Categorization based on:

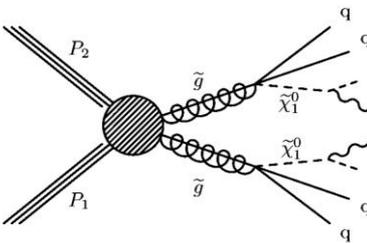
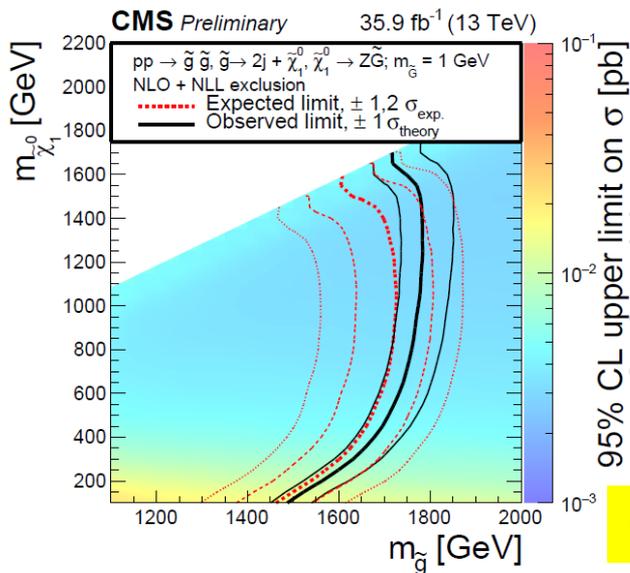
N_{jets}

$N_{b\text{ jets}}$

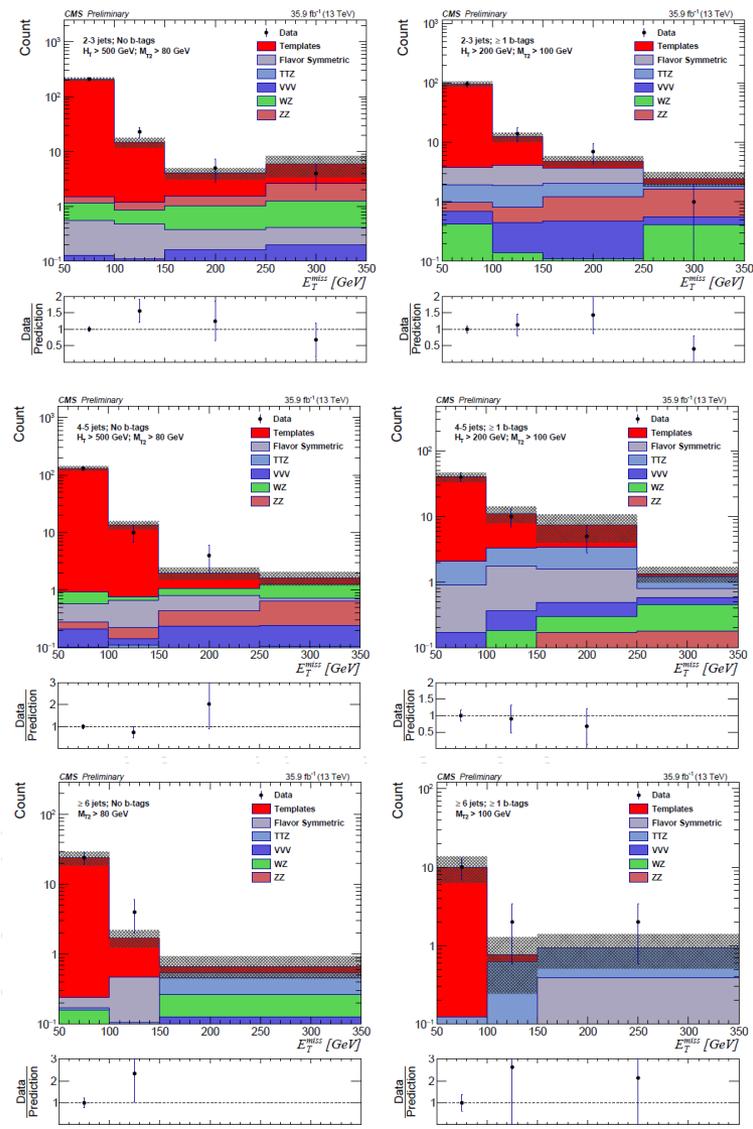
p_T^{miss}

Dominant background:

Z+jets
ttZ



CMS-PAS-SUS-16-034



Opposite sign dilepton (Edge)



Selection:

- 2 leptons, opposite charge**
- ≥ 2 jets
- $m_{\ell\ell} > 20$ GeV, $\notin [86, 96]$ GeV
- $p_T^{\text{miss}} > 150$ GeV
- $\Delta\phi(\vec{p}_T^{\text{miss}}, j_{1,2}) > 0.4$
- $M_{T2}^{\ell\ell} > 80$ GeV
- H_T dependent on N_{jets} and $N_{b \text{ jets}}$

Categorization based on:

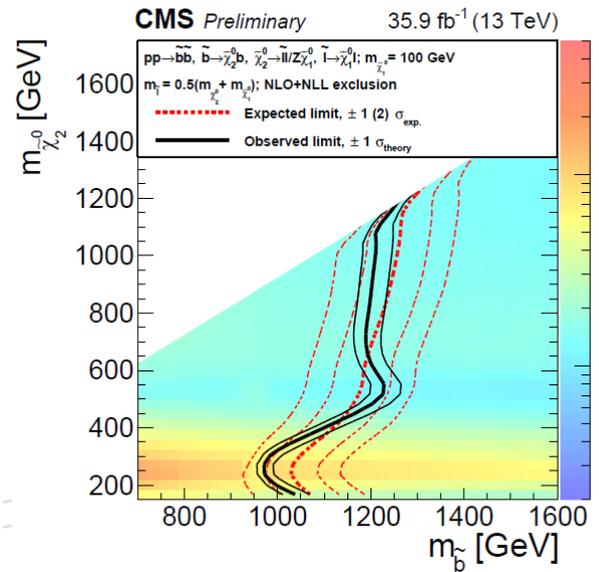
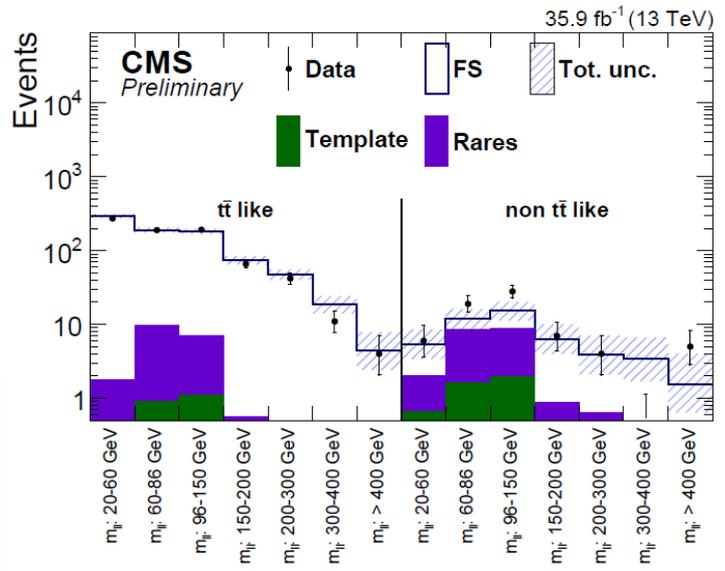
$t\bar{t}$ likelihood

$m_{\ell\ell}$

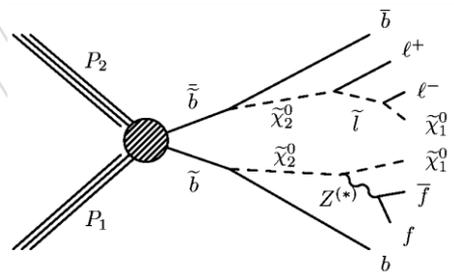
Dominant background:

$t\bar{t}$

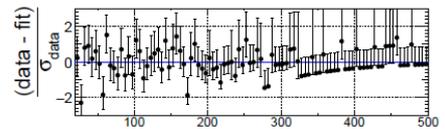
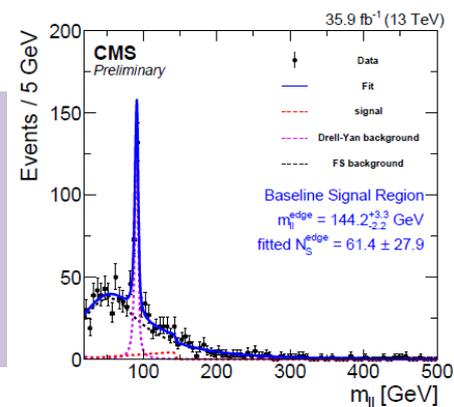
WW, Z $\rightarrow\tau\tau$, $t\bar{t}Z$, WZ



95% CL upper limit on σ [pb]

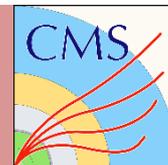


Binned cut-and-count and fit using predicted edge shape



CMS-PAS-SUS-16-034

Same sign dilepton



Selection:

2 leptons, same charge

≥ 2 jets

$p_T^{\text{miss}} > 50$ GeV

$m_{\ell\ell} > 8$ GeV

Dominant background:

Nonprompt or
misidentified leptons

WZ, $t\bar{t}W$, $t\bar{t}Z$

CMS-PAS-SUS-16-035

Categorization based on:

$p_T^{\ell 1}, p_T^{\ell 2}$ (HH, HL, LL) p_T^{miss}

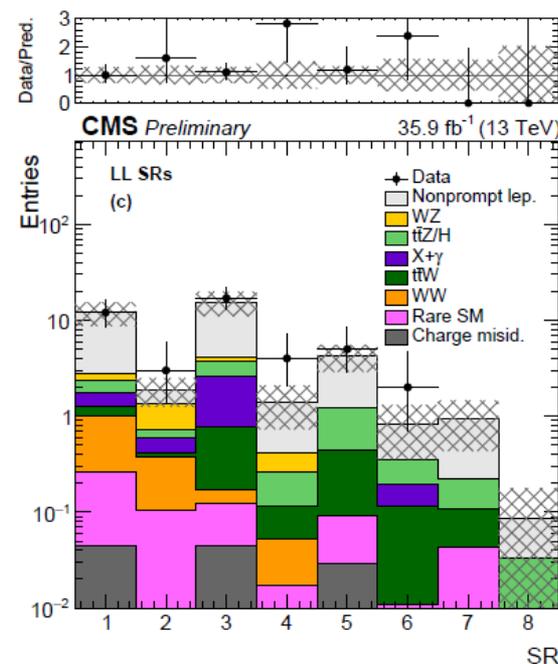
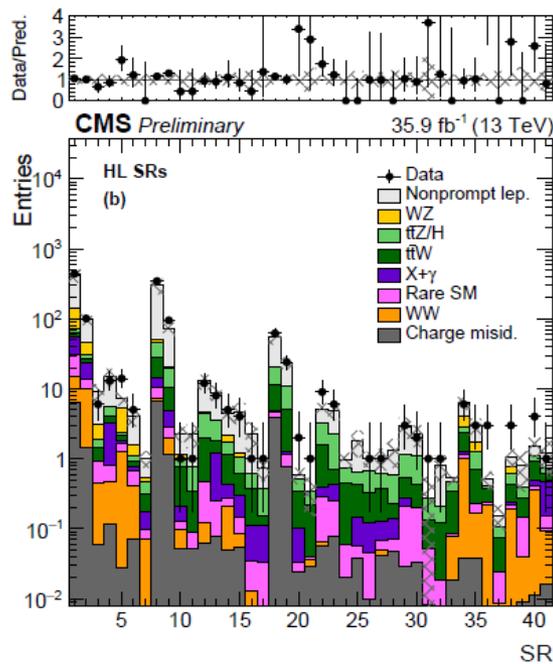
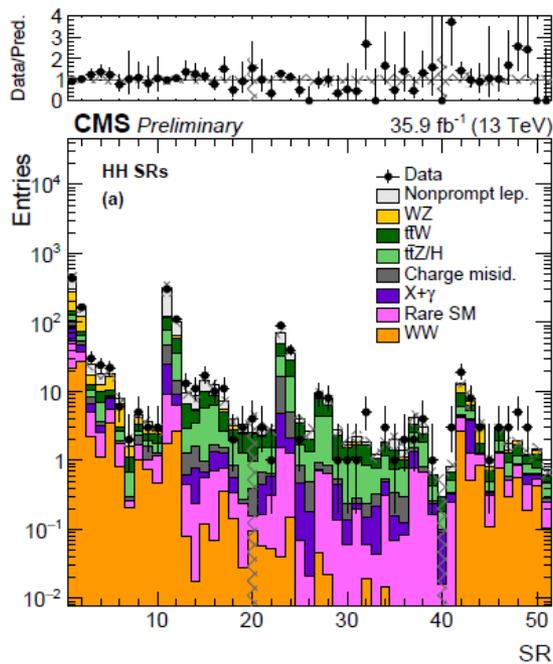
Charge (++, --)

$N_{\text{b jets}}$

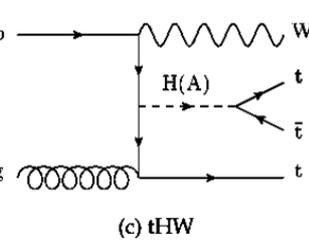
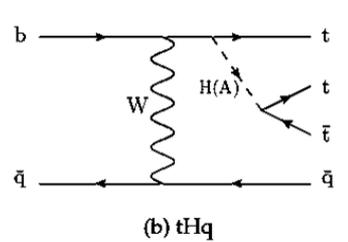
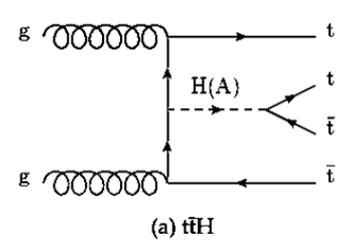
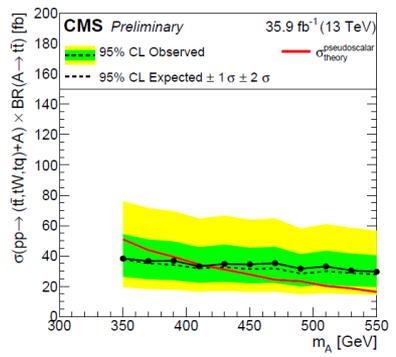
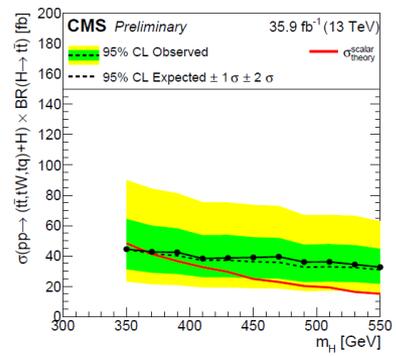
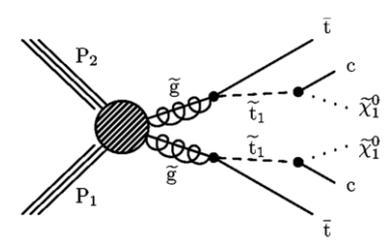
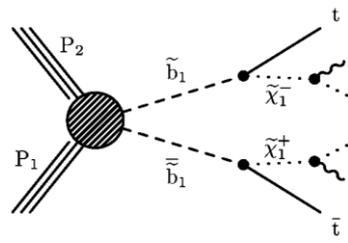
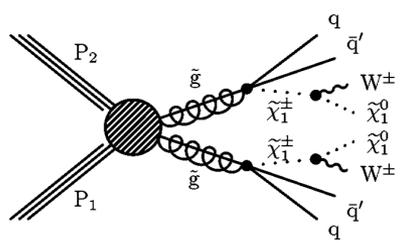
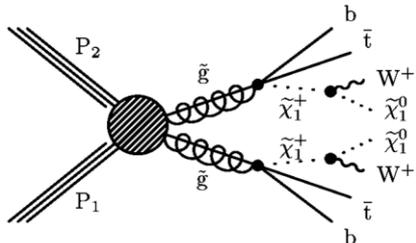
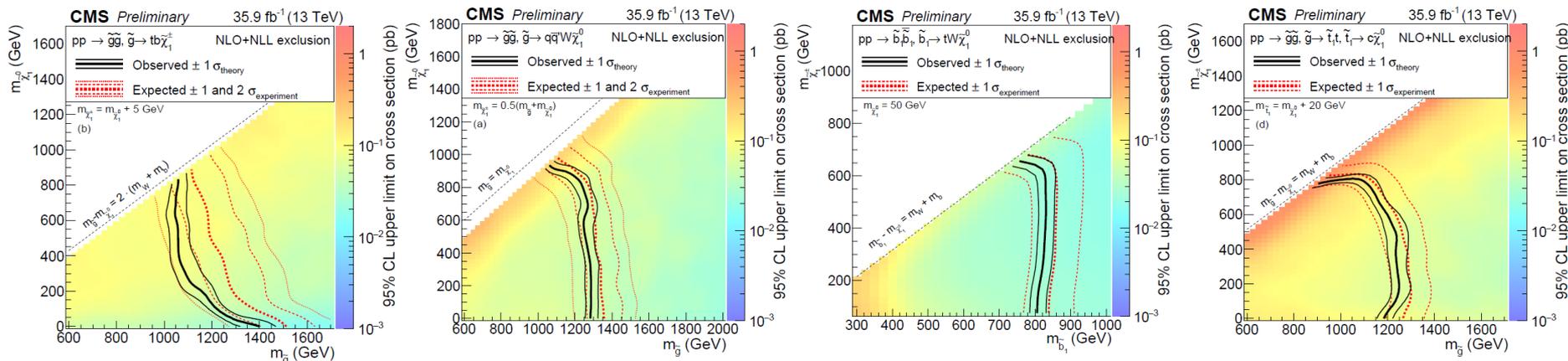
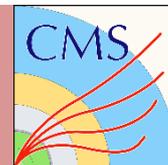
N_{jets}

H_T

M_T^{min}



Same sign dilepton



CMS-PAS-SUS-16-035

Multileptons



Selection:

≥ 3 leptons

≥ 2 jets

$p_T^{\text{miss}} > 50$ GeV (70 in on-Z categories with low N_{bjets} and H_T)

$m_{\ell\ell} > 12$ GeV (OSSF pairs)

Dominant background:
 Nonprompt or
 misidentified leptons (off-Z)
 WZ, $t\bar{t}Z$ (on-Z)

CMS-PAS-SUS-16-041

Categorization

based on:

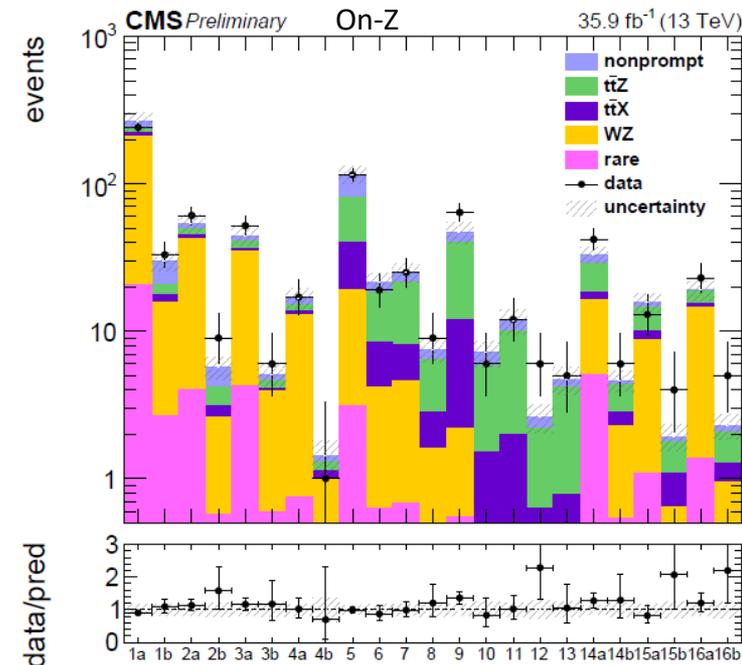
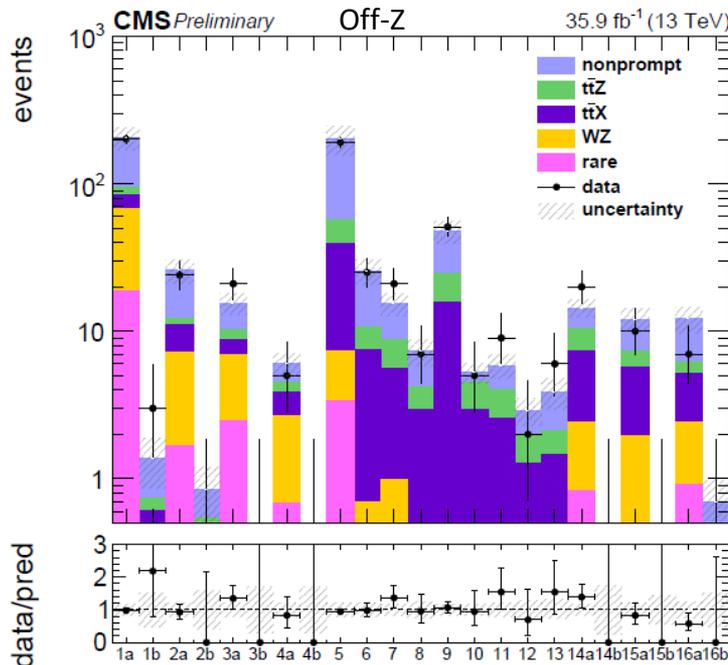
Off-/On-Z

N_{bjets}

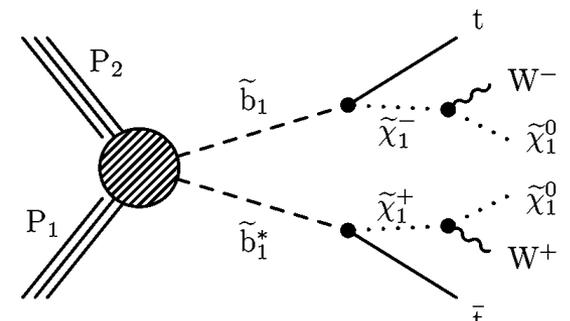
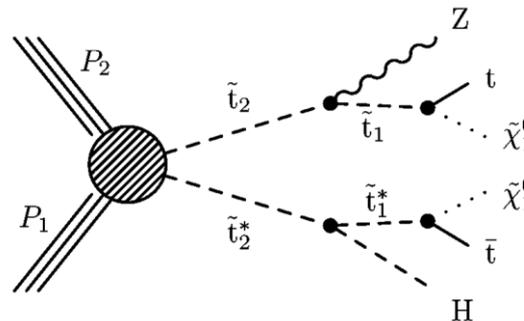
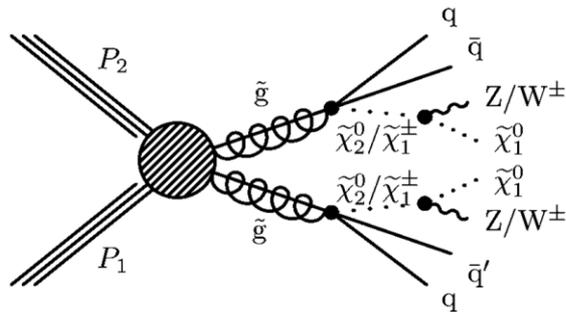
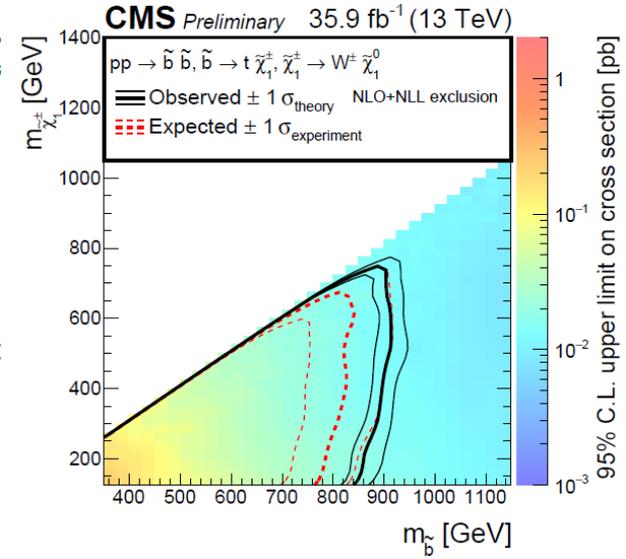
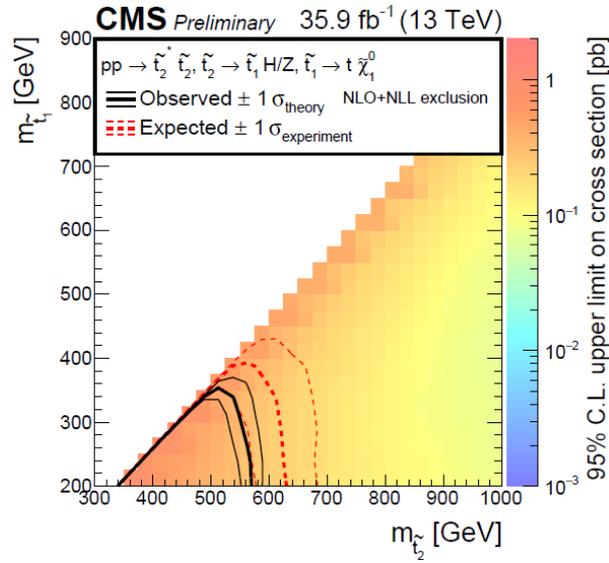
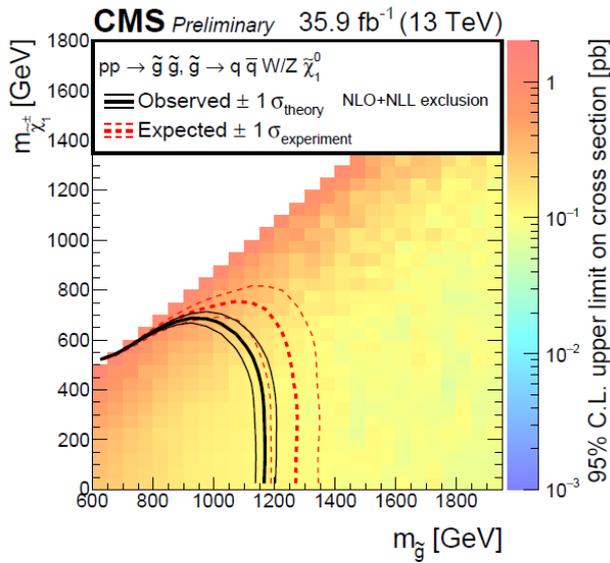
p_T^{miss}

H_T

M_T^{min} (non-Z ℓ)

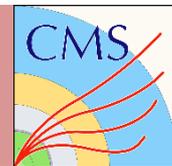


Multileptons

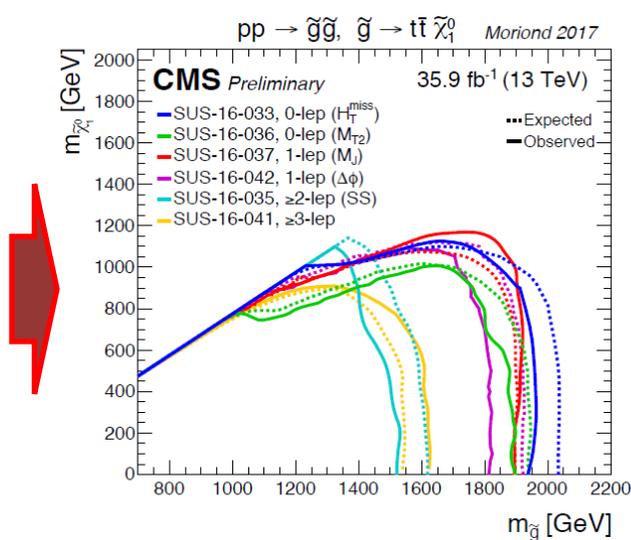
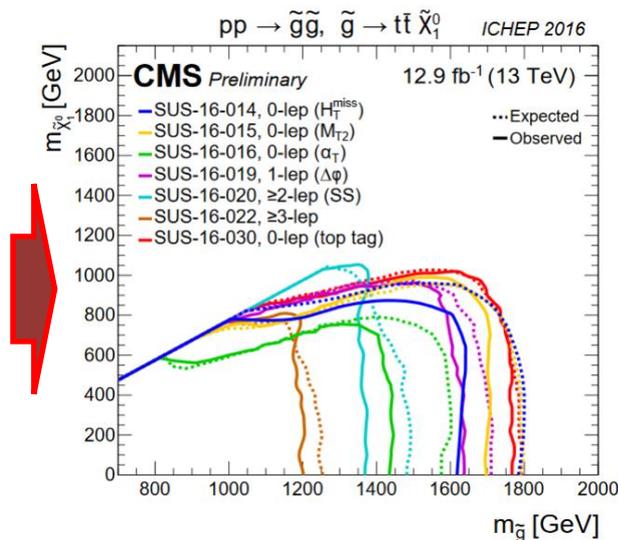
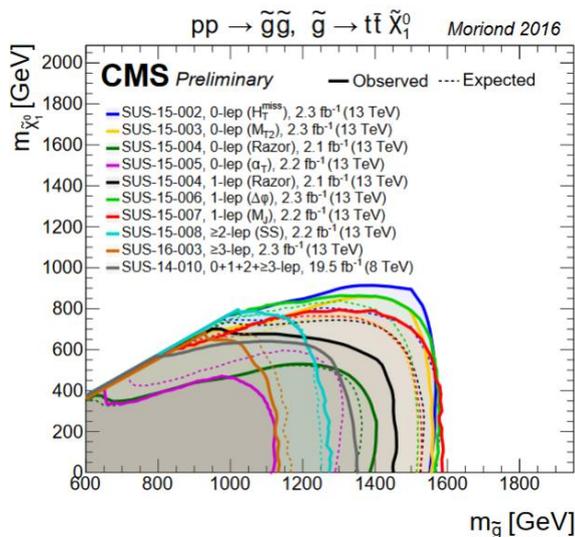


CMS-PAS-SUS-16-041

Conclusions



- A quick overview of the most recent CMS new physics searches based on strong SUSY models with leptonic and fully hadronic final states has been presented.
- The excluded sparticle mass ranges (from simplified models) grow every year.
 - Should we start forgetting about “natural” SUSY?
 - Could strong sparticles be (just) beyond LHC reach? (we could still have EW!)
 - Now may be the time to think about all of this, but nevertheless...



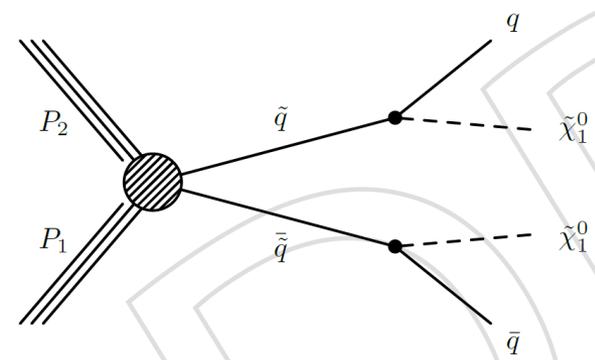
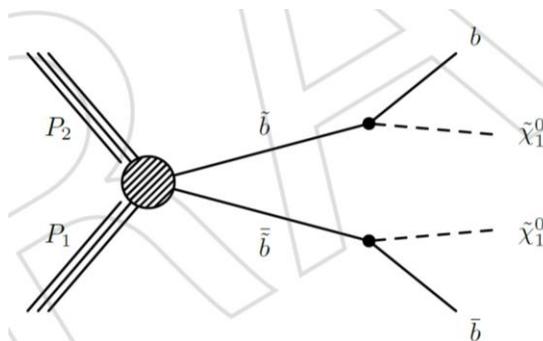
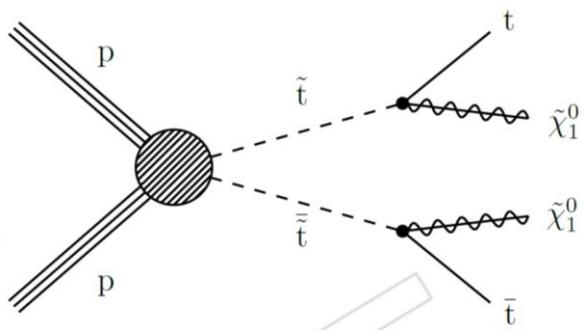
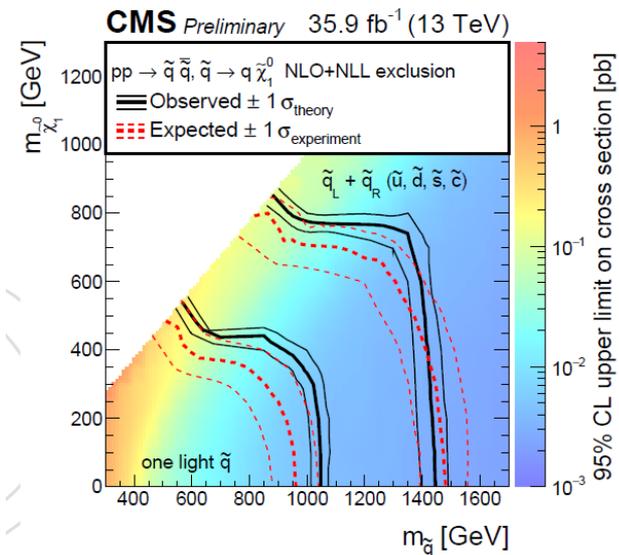
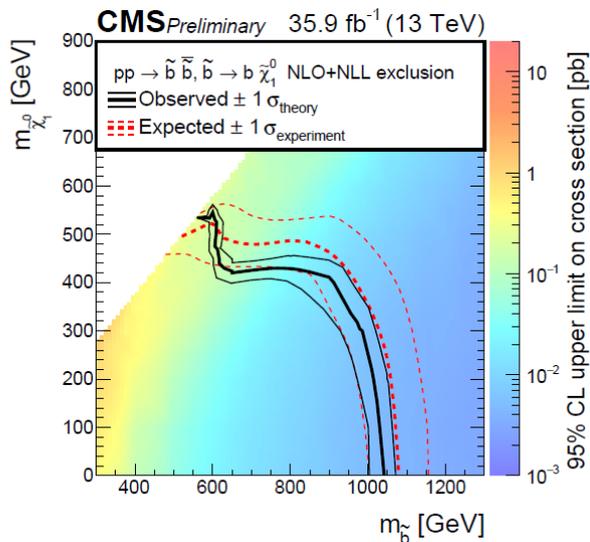
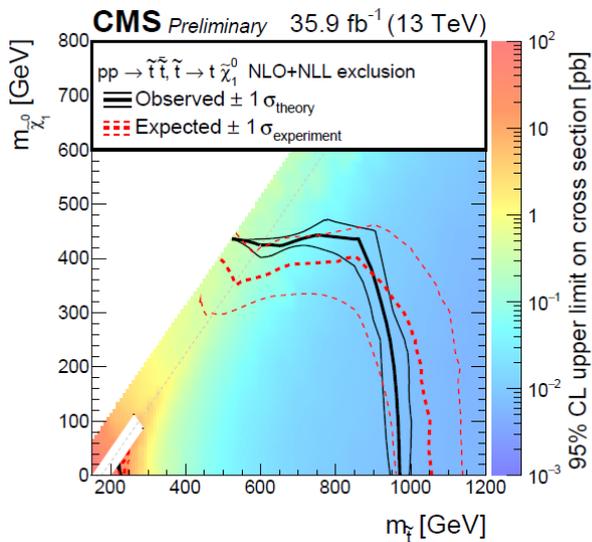
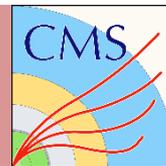


**KEEP
CALM
AND
COLLIDE
HADRONS**

Thank you for your attention!

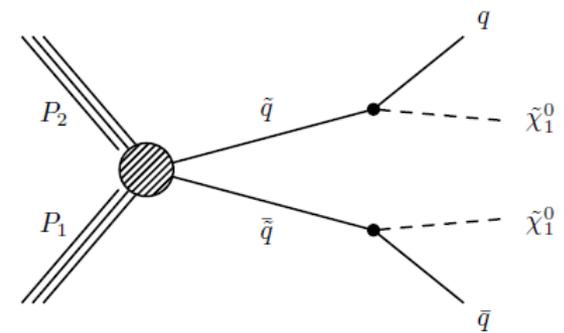
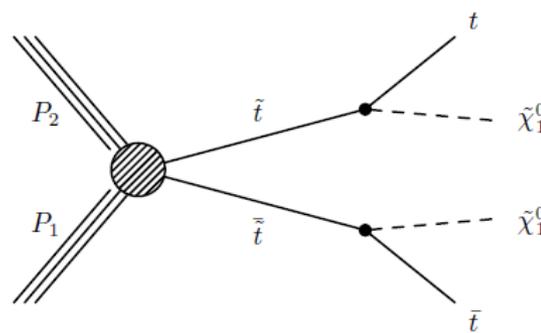
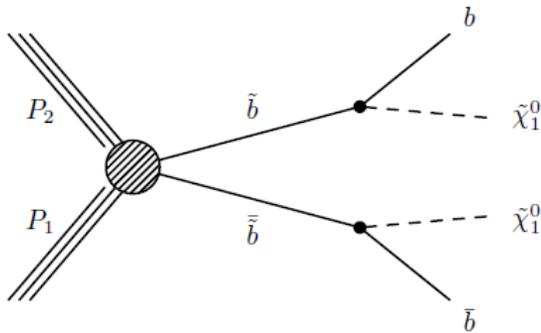
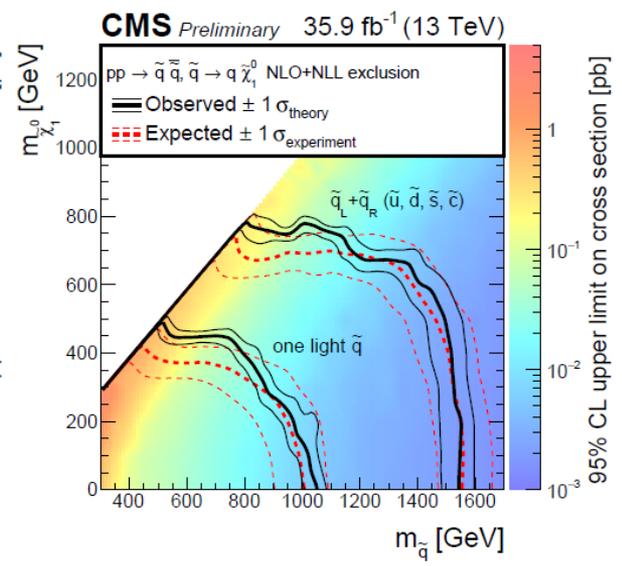
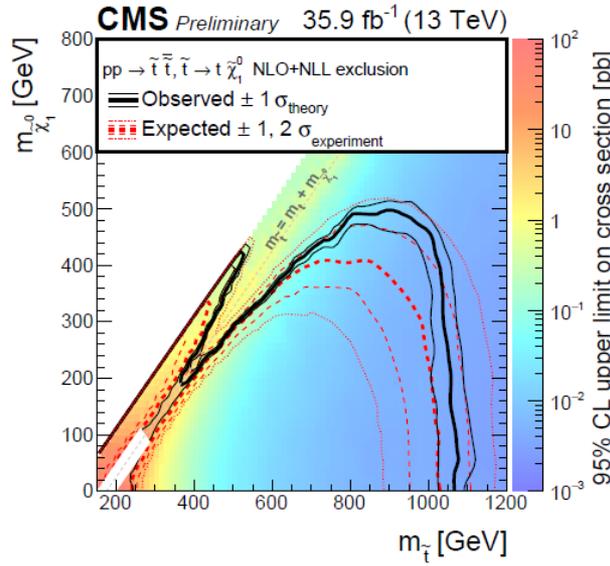
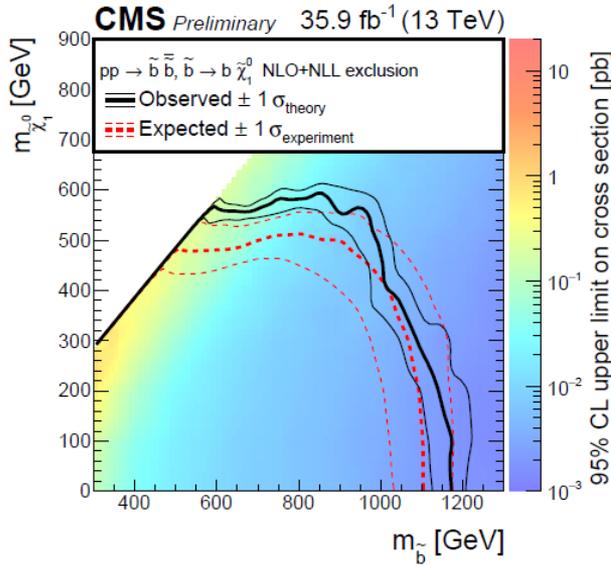
Backup

Jets with H_T^{miss}



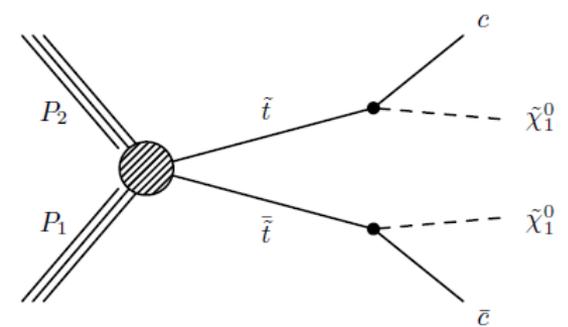
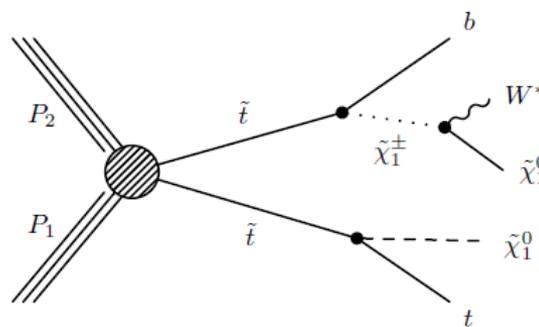
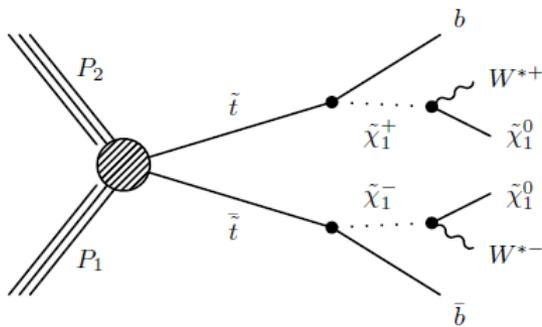
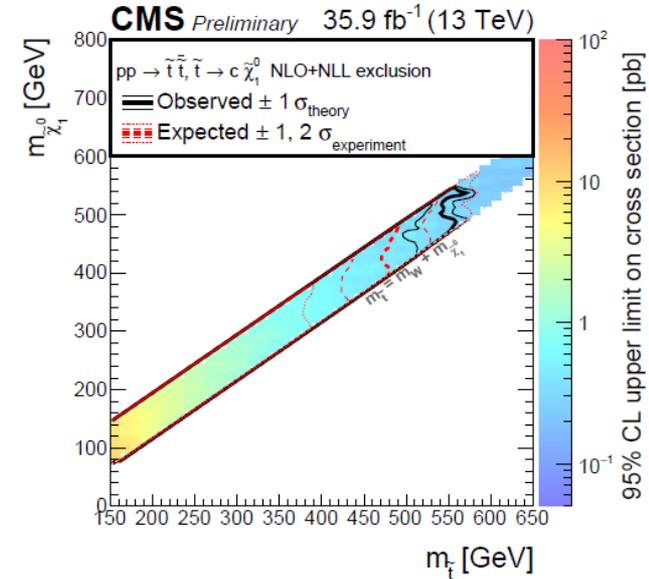
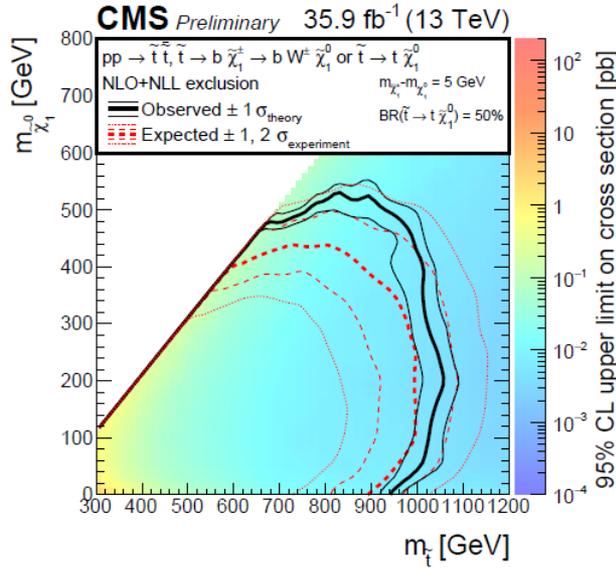
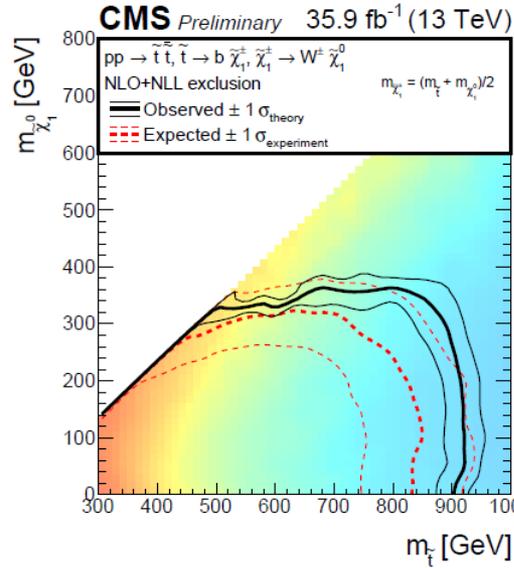
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Jets with M_{T2}



CMS-PAS-SUS-16-036

Jets with M_{T2}

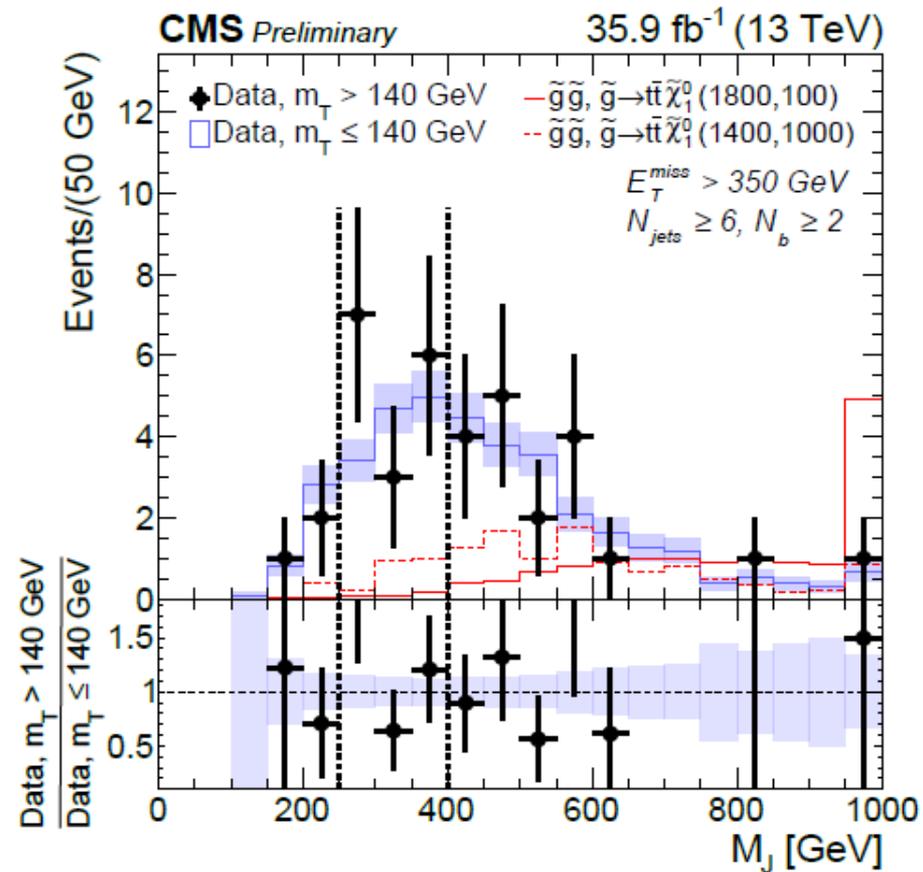
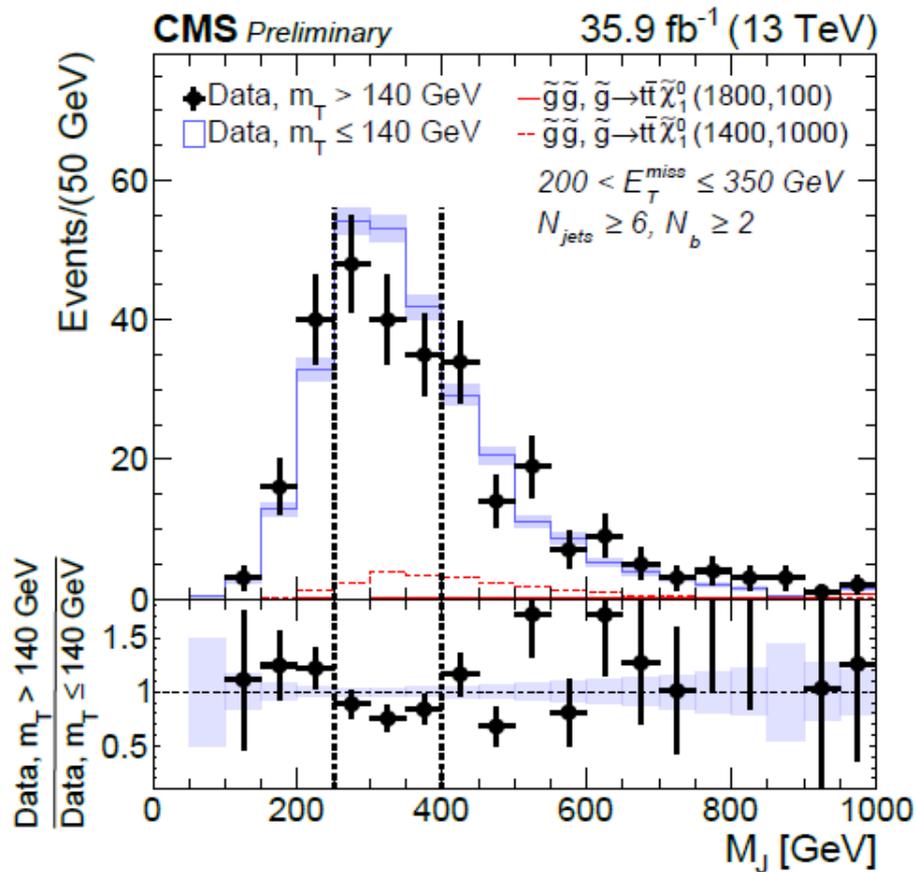


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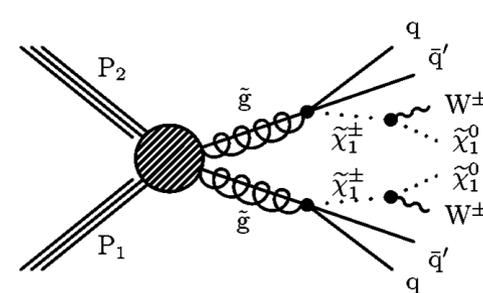
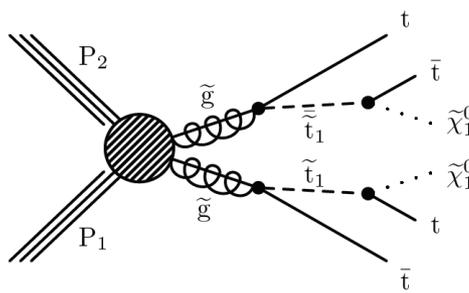
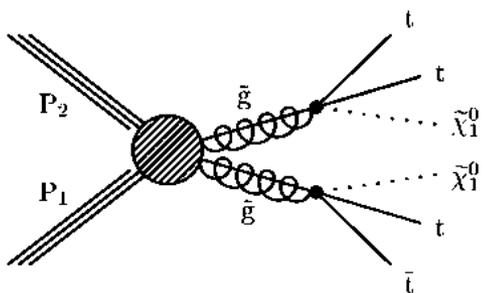
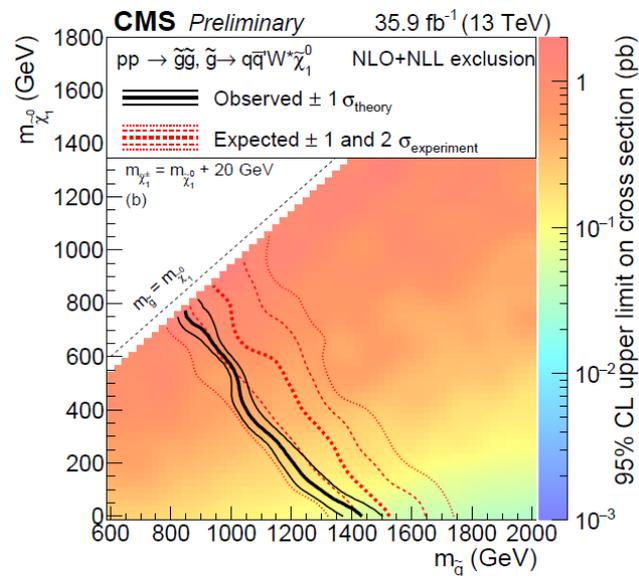
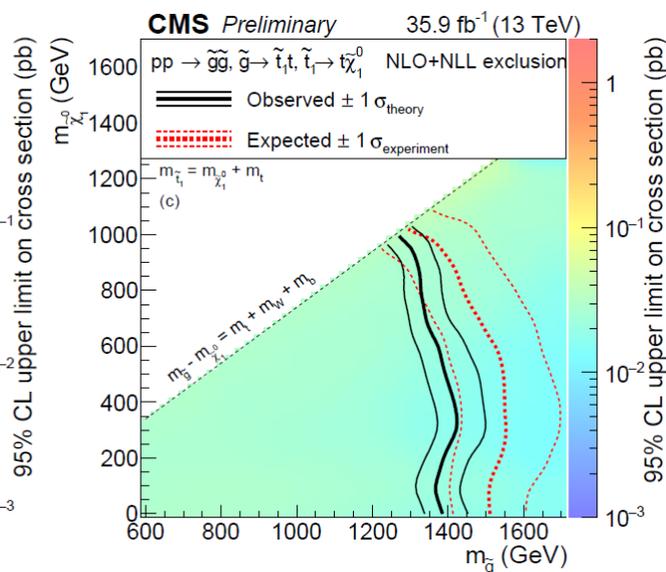
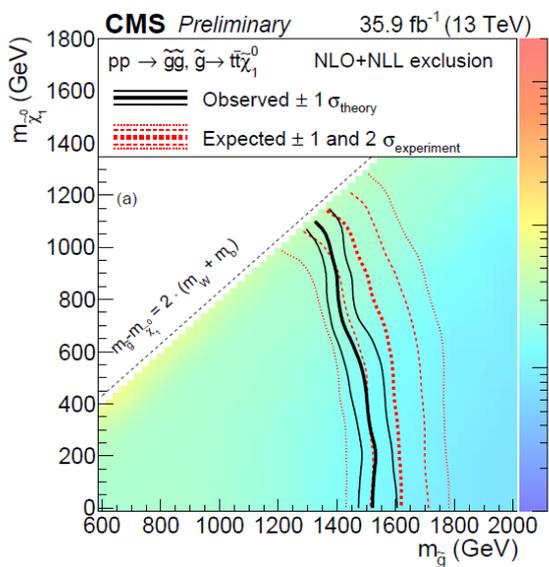
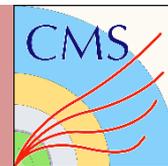
1 lepton with M_J



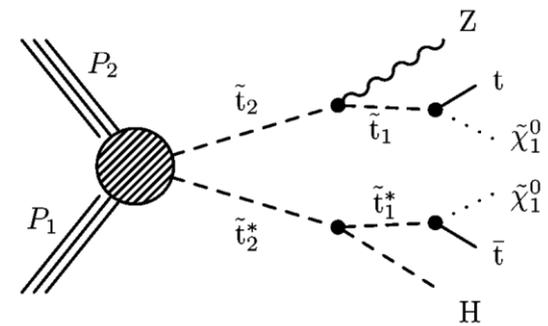
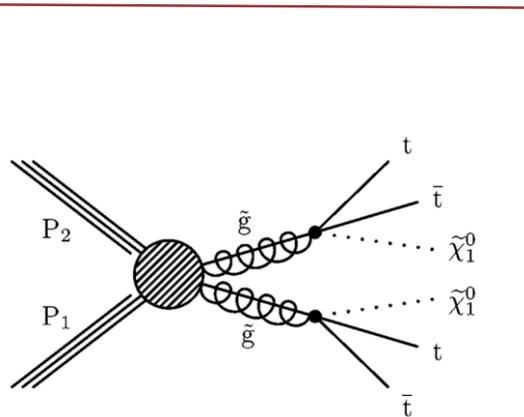
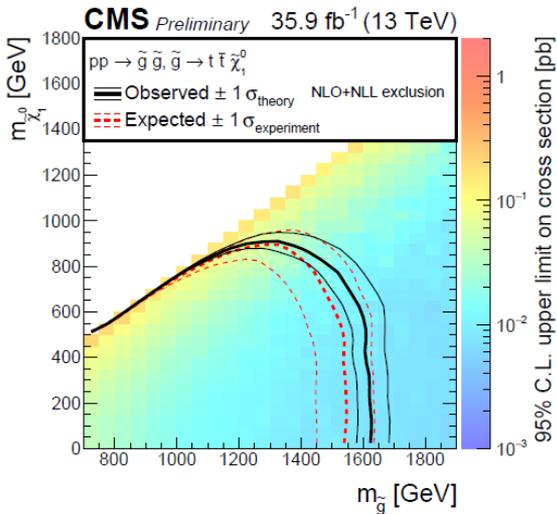
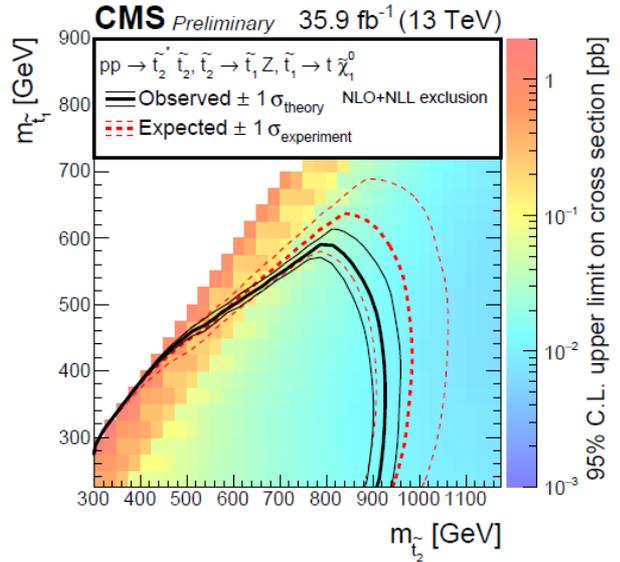
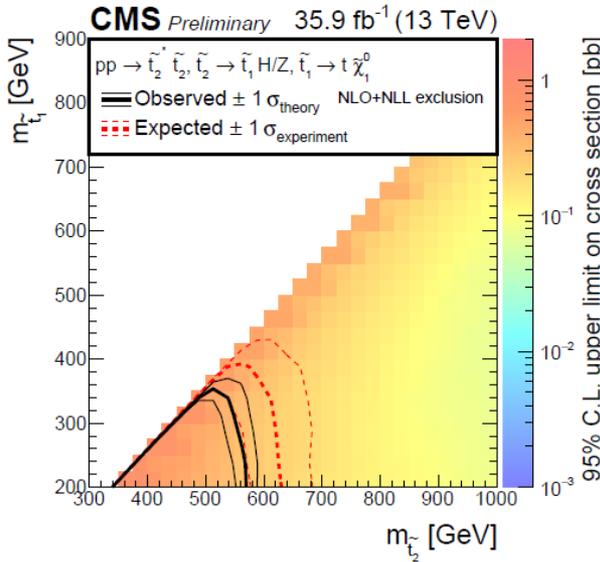
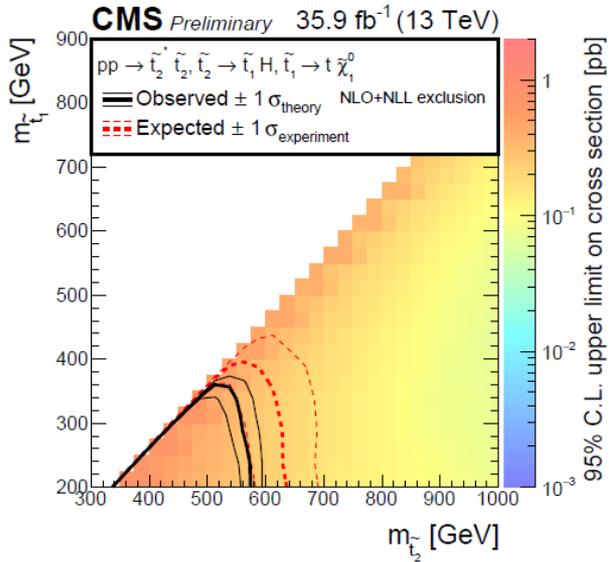
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Same sign dilepton



Multileptons



CMS-PAS-SUS-16-041