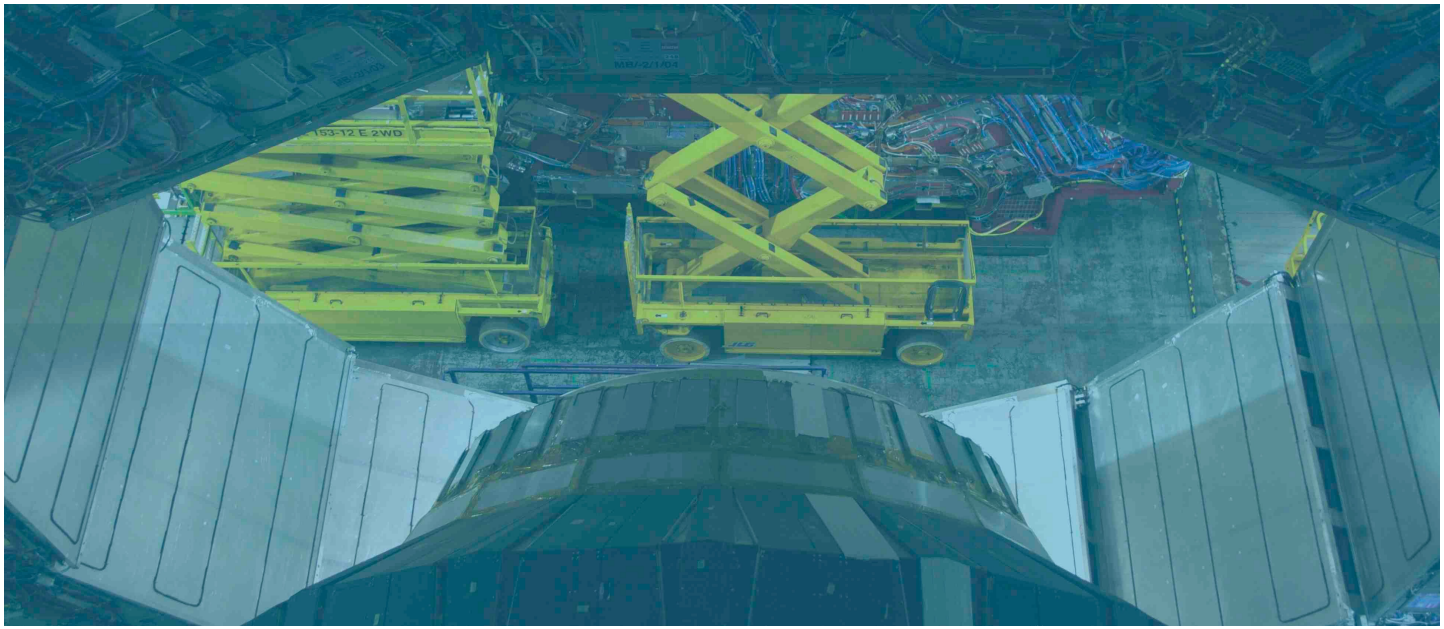
# Squark & gluino searches in leptonic channels with CMS



**Artur Lobanov**
*DESY Hamburg*
on behalf of the **CMS** Collaboration

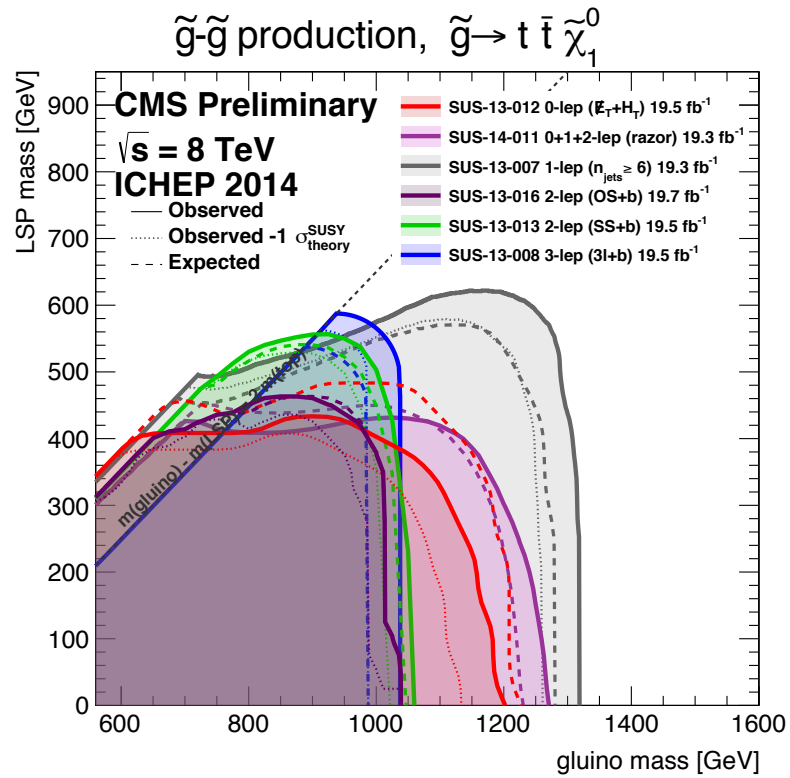
**16 June 2016**
**4th Large Hadron Collider Physics Conference**
**Lund, Sweden**

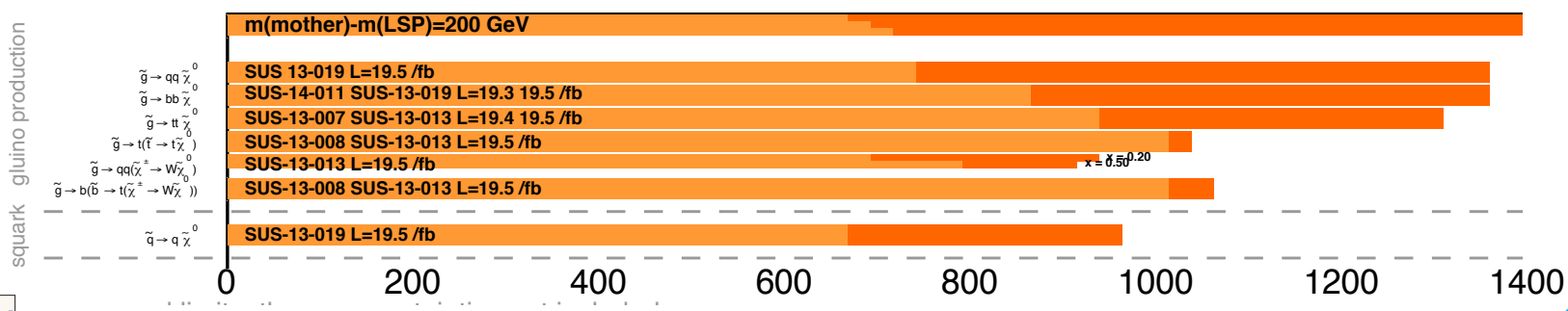
# Strong SUSY after LHC Run1

Interpretation within

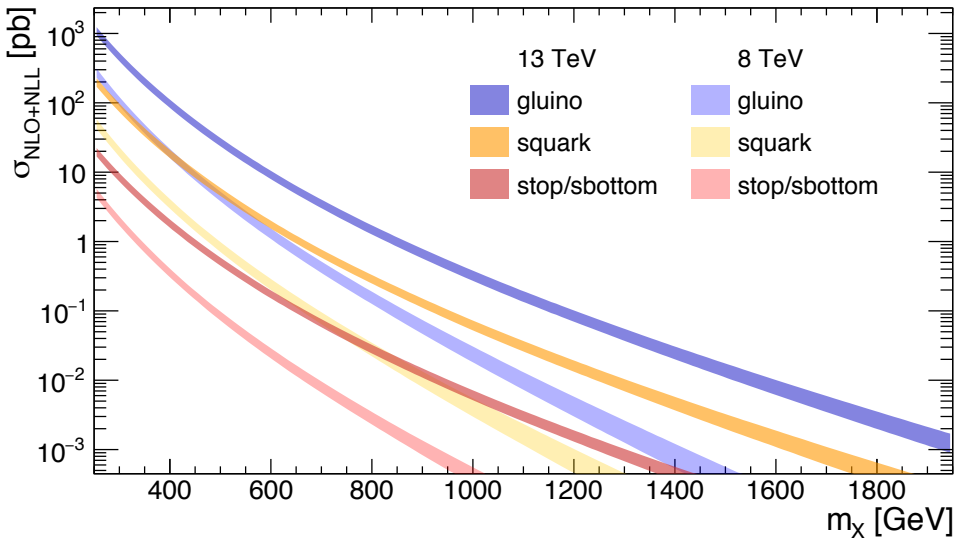
*simplified models*:

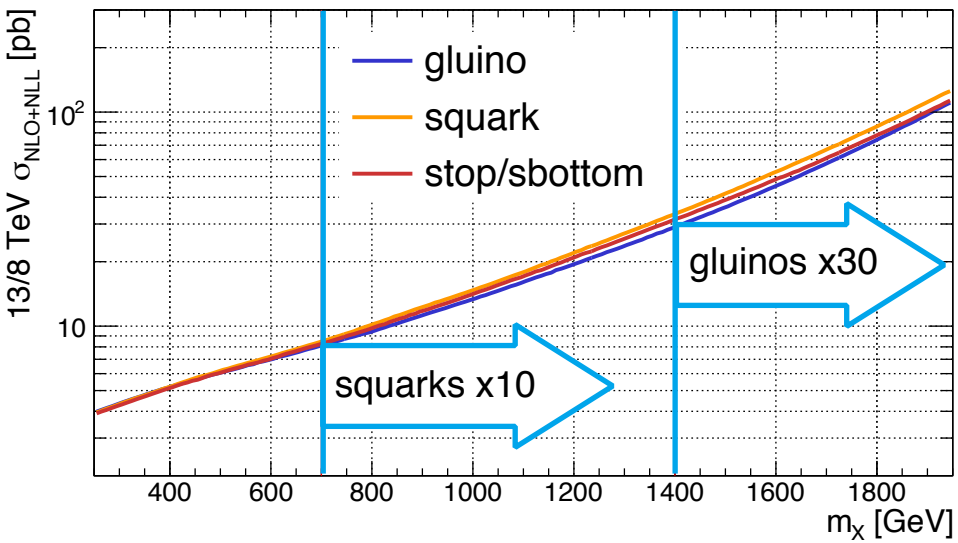
- Gluinos excluded in various searches > 1400 (700) GeV for light (heavy) neutralinos
- Squarks excluded above 900 (700) GeV for light (heavy) neutralinos



# Strong SUSY at the LHC with √s = 13 TeV




- Strong SUSY profits largely from increased √s
- Gluino with largest absolute xsec and also largest gain wrt 8TeV for excluded $m_{gluino}$
- In this talk: gluino/squark searches at CMS using 2015 data at √s = 13 TeV
- See Eric's talk for 3rd gen SUSY in the afternoon

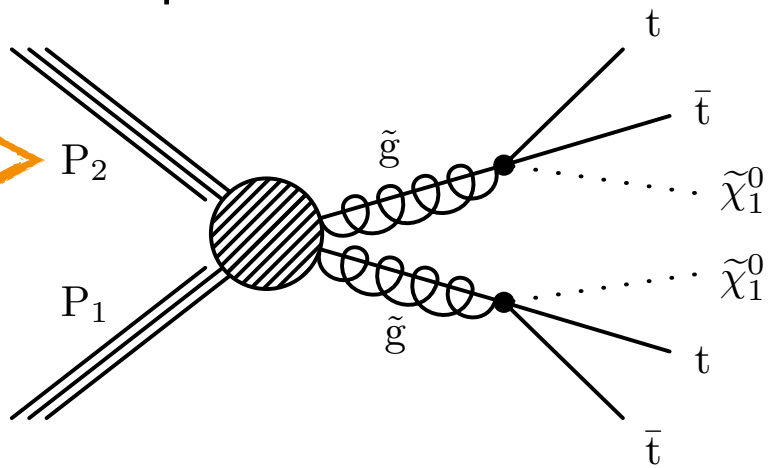
- Xsec source

# Leptonic gluino searches at CMS

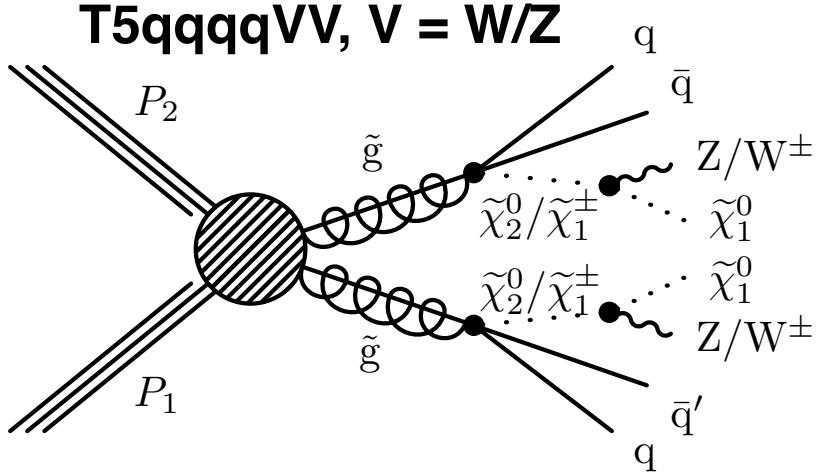
- Leptons in gluino production:
  - W from top quarks
  - W/Z from charginos
- Leptonic channels:

=1$\ell$ — high BR, inclusive
≥2$\ell$ — moderate BR, low SM
≥3$\ell$ — low BR and ~no SM

Simplified Model: **T1tttt**




**T5qqqqVV, V = W/Z**




(various EWKino mass splittings)

# Leptonic gluino searches at CMS

- Leptons in gluino production:
  - W from top quarks
  - W/Z from charginos
- Leptonic channels:

  $=1\ell$ — high BR, inclusive

  $\geq 2\ell$ — moderate BR, low SM

  $\geq 3\ell$ — low BR and ~no SM

- SUS-15-004 (Razor*)
- SUS-15-006 ($\Delta\phi$)
- SUS-15-007 ($M_J$)
- SUS-16-011 (Soft)

- SUS-15-008 (SS)
- SUS-15-011 (OS)

- SUS-16-003 ($\geq 3\ell$)

*All-hadronic searches — see Talk by Tai from Tuesday

# SUS-15-006 (1ℓ, Δϕ)

CMS-PAS-SUS-15-006

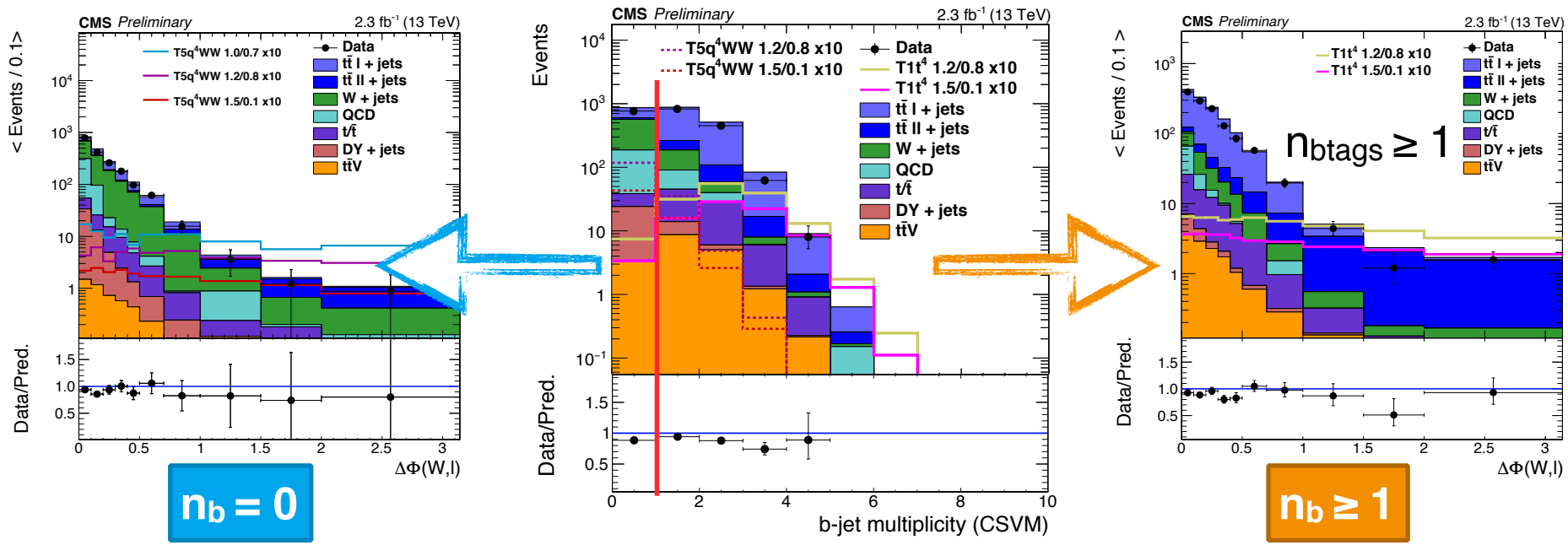
Targets T5qqqqWW & T1tttt with single isolated e/μ $p_T > 25$ GeV

Preselection:

- $L_T = MET + p_T$ (lepton) > 250 GeV
- $n_{jets} \geq 5$ ($p_T > 30$ GeV)
- $H_T = \sum p_T$ (jets) > 500 GeV

Signal discrimination

- $\Delta\phi(W,\ell)$ — azimuthal angle between lepton and reconstructed $W(\overrightarrow{MET+\ell})$

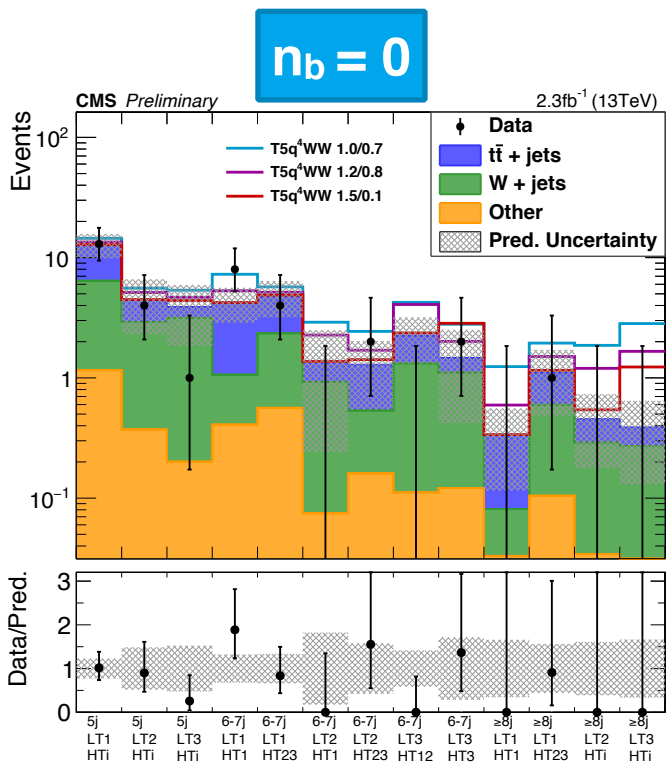


# SUS-15-006 (1ℓ, Δϕ)

CMS-PAS-SUS-15-006

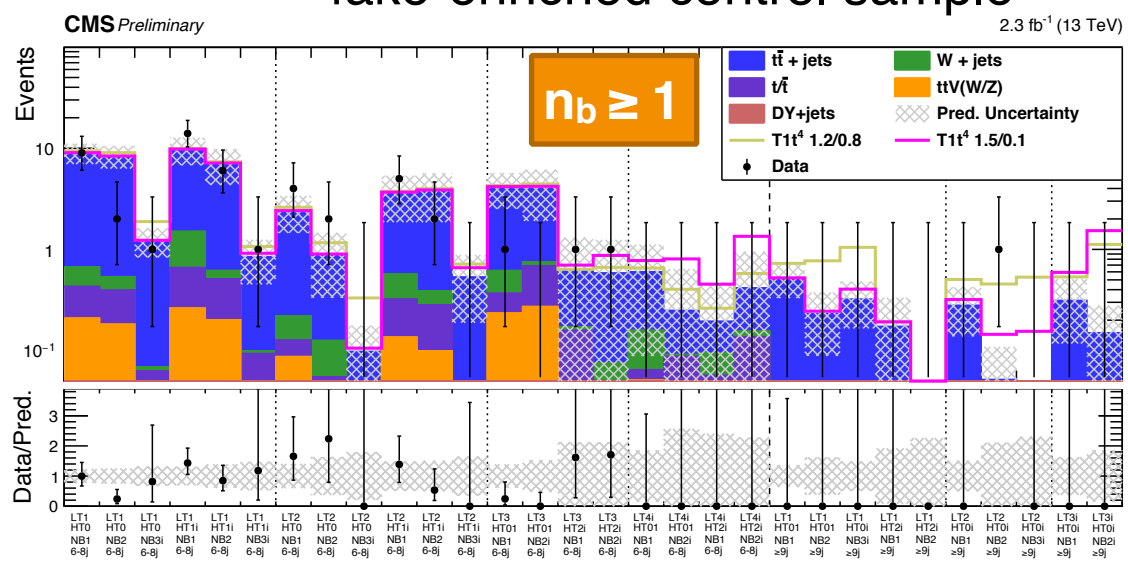
Multi-bin search with ABCD-like background prediction based on Δϕ & $n_{jets}$

- Exclusive search bins in $H_T$, $L_T$, $n_j$, $n_b$
- Total regions: 13 (30) for $n_{btags} = 0$ (≥ 1)




## Data-driven background estimation

- High-to-low Δϕ transfer factors from low $n_j$ data sidebands ($R_{CS}$)
- Residual corrections between $n_j$ bands from MC
- QCD contribution estimated from fake-enriched control sample




—> good agreement with observation

# SUS-15-007 (1ℓ, $M_J$)

arXiv:1605.04608

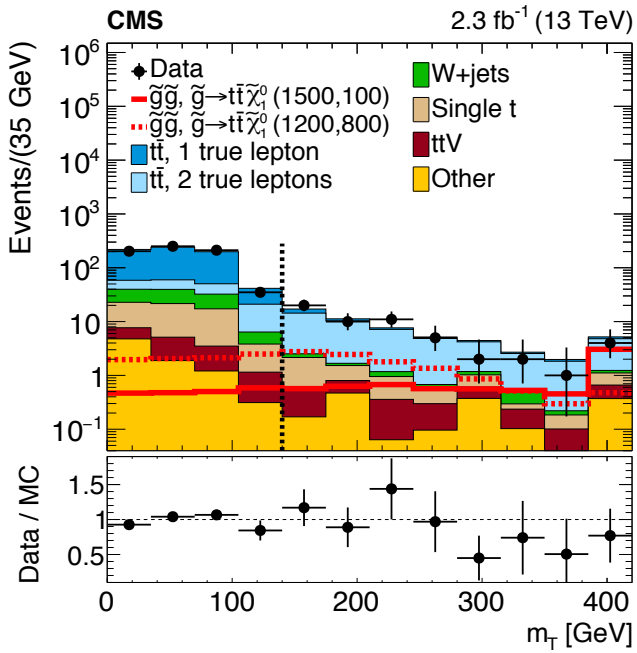
Targets T1tttt with single isolated e/μ $p_T > 20$ GeV

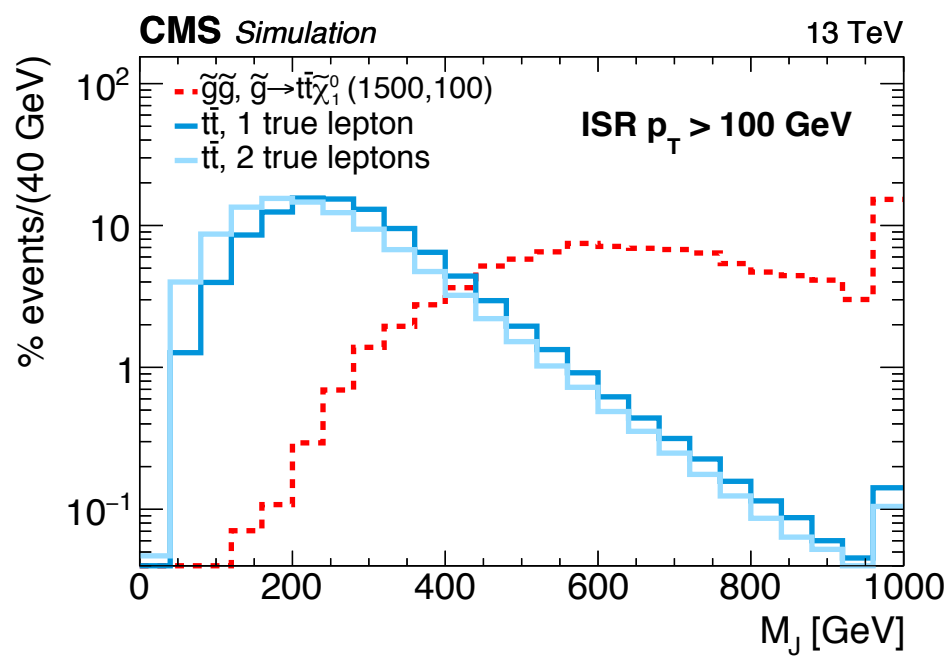
Preselection:

- $n_{jets} \geq 6$ ($p_T > 30$ GeV), $n_b \geq 1$
- $H_T = \sum p_T$ (jets) > 500 GeV
- MET > 200 GeV

Signal discrimination

- $m_T$: from MET and lepton
- $M_J$: sum of large-R(1.2) jet masses



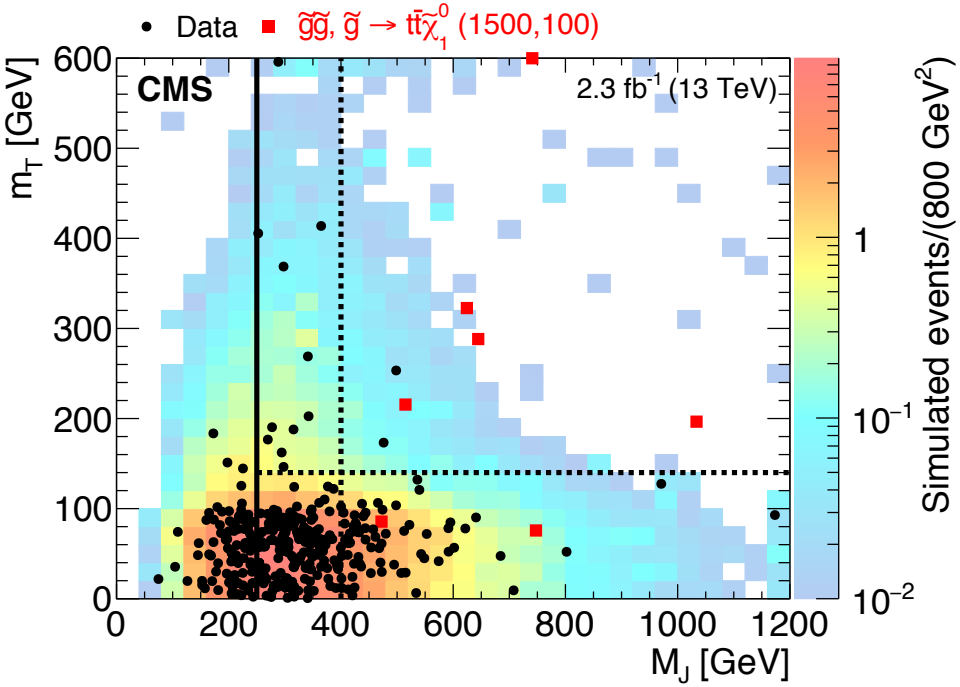

tt+jets background dominates —> suppressed by $M_J$ cut

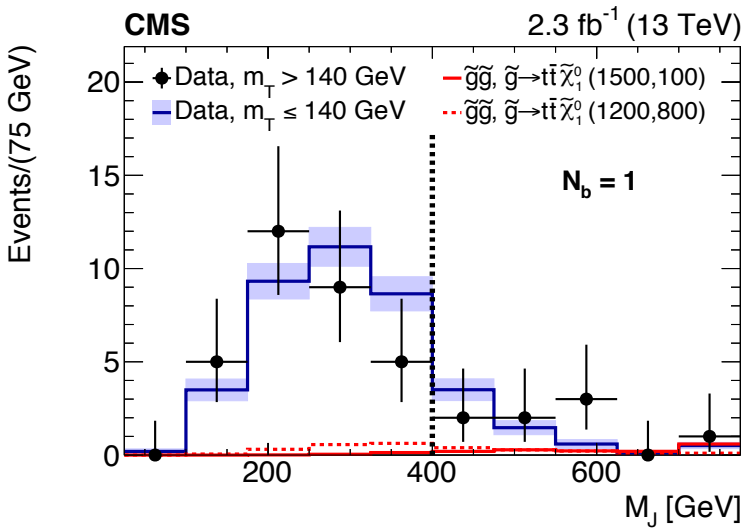
# SUS-15-007 (1ℓ, $M_J$)

arXiv:1605.04608

Multi-bin search with ABCD-like background prediction

- Exclusive search bins in MET, $n_j$ and $n_b$
- Total regions: 10




## Data-driven background prediction

- $m_T$ and $M_J$ not correlated
- Low-to-high $m_T$ transfer factors
- Residual corrections between $M_J$ regions from MC
- Prediction from fit in each bin

**—> agrees with observation**

# SUS-16-011 (1ℓ, soft leptons)

CMS-PAS-SUS-16-011

Targets T5qqqqWW with single soft e/μ $5 < p_T < 20$ GeV

Preselection:

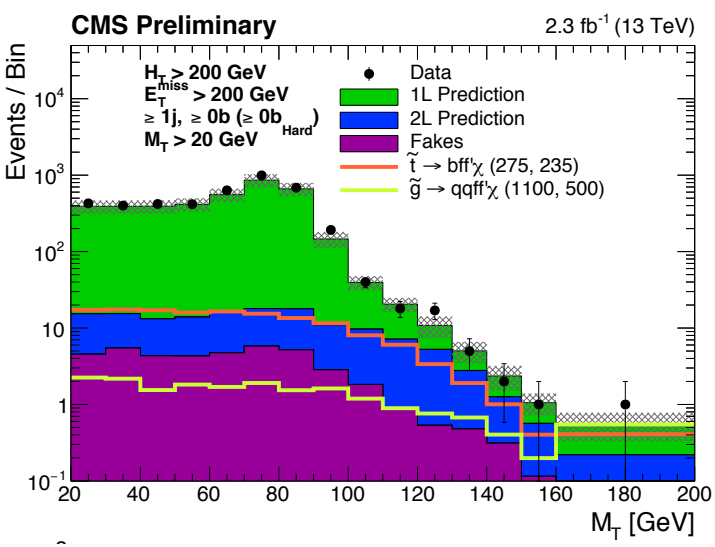
- No second lepton/isolated track
- $H_T = \sum p_T$ (jets) > 200 GeV
- MET > 200 GeV
- $|MET - H_T| < 0.5$ MET
- $n_{jets} \geq 1$
- $m_T > 20$ GeV

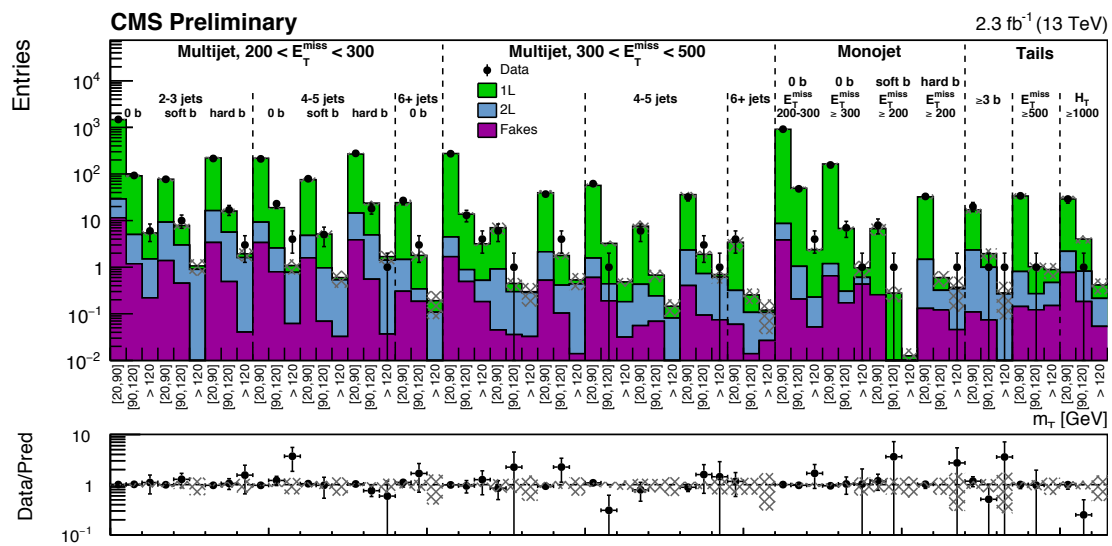
Search bins in $H_T$, MET, $m_T$, $n_{jets}$, $n_{btags}$

Background estimation in categories:

- 1ℓ — from hard muon, low MET CR
- 2ℓ — from 2ℓ control region
- Fakes from fake-enriched sample

**—> agrees with observation**




More details in Giovanni's talk

# SUS-15-008 (same-sign 2ℓ)

arXiv:1605.03171

Targets various scenarios with two same-sign e/μ

Preselection:

- SS e/μ with $p_T > 15/10$ GeV
- Any $m_{\ell\ell} > 12$ GeV and outside Z
- $n_{jets} \geq 2$ ($p_T > 40$ GeV)
- $H_T = \sum p_T$ (jets) > 500 GeV
- MET > 50 GeV

Signal discrimination:

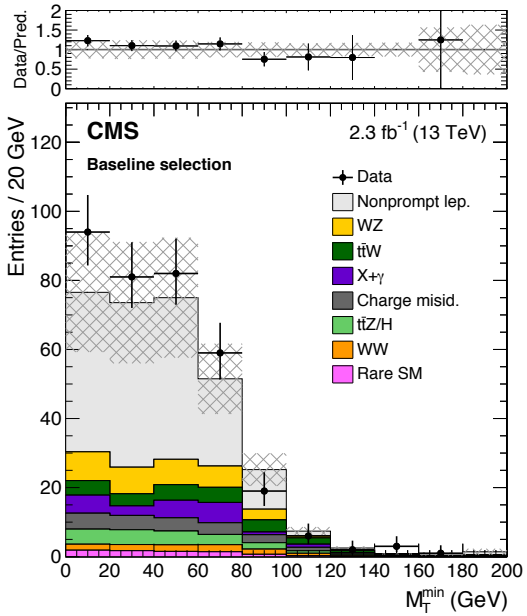
- min($m_T$) of two leptons

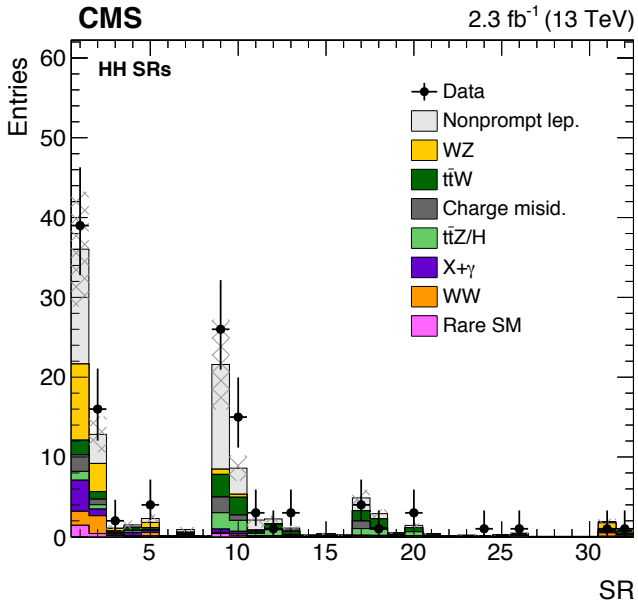
Search categories based on $p_T$ of leptons and binned in $m_T$, $H_T$, MET, $n_{jets}$, $n_{btags}$

Background estimation in categories:

- Nonprompt from loose leptons in data
- Same-sign 2ℓ SM processes from MC
- Charge misidentified from OS data

—> **agrees with observation**



# SUS-16-003 (multileptons)

CMS-PAS-SUS-16-003

Targets T1tttt & T5qqqqVV with multileptons

Preselection:

- 3 e/μ with $p_T$ > 20/15/10 GeV
- OS SF $m_{\ell\ell}$ > 12 GeV
- $n_{jets} \geq 2$ ($p_T$ > 30 GeV)
- $H_T = \sum p_T$ (jets) > 60 GeV
- MET > 50 GeV

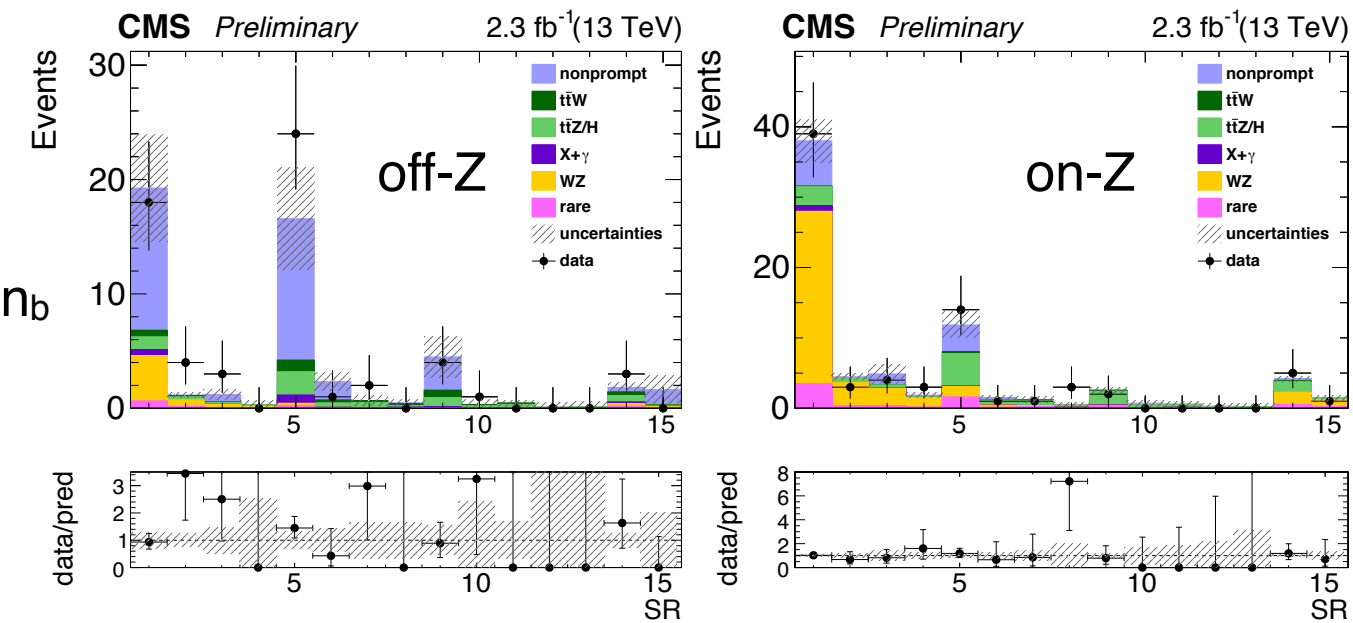
Search categories:

- $m_{\ell\ell}$ on/off-Z peak
- binned in $H_T$, MET, $n_b$

Background estimation in categories:

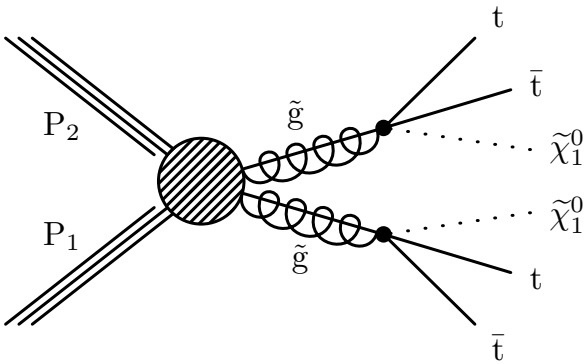
- Nonprompt from loose leptons in data
- Dibosons from normalised MC
- Rare SM processes from MC

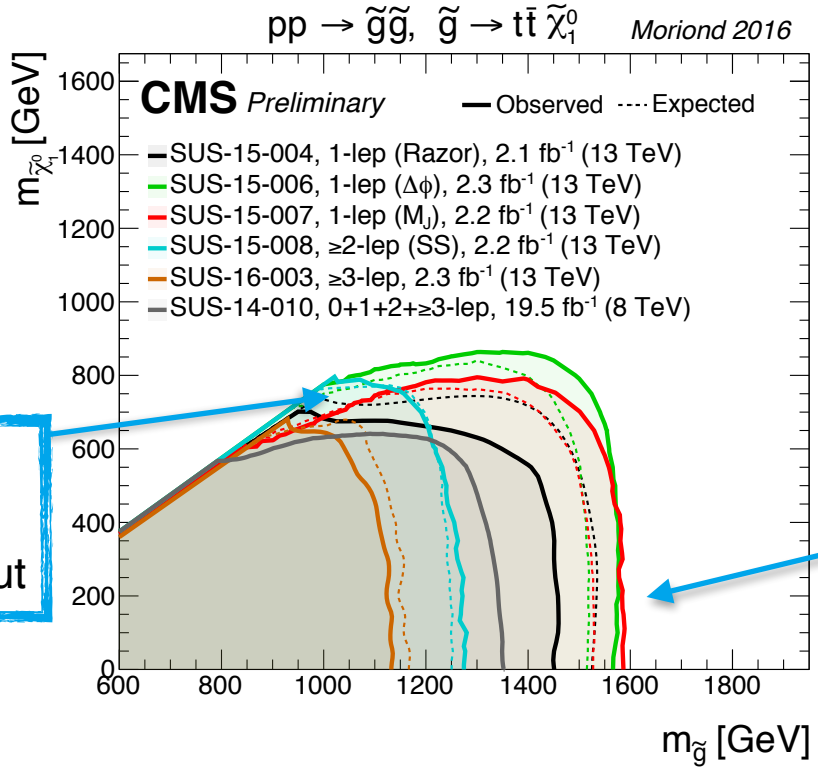
—> **agrees with observation**



# Limit summary: T1tttt

- 1ℓ analyses most sensitive and comparable to full hadronic
- Significant extension beyond 8TeV results



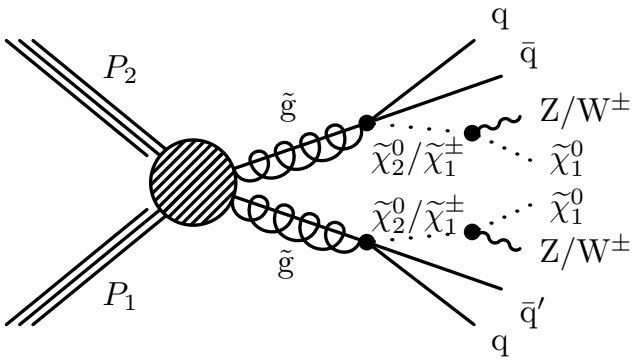



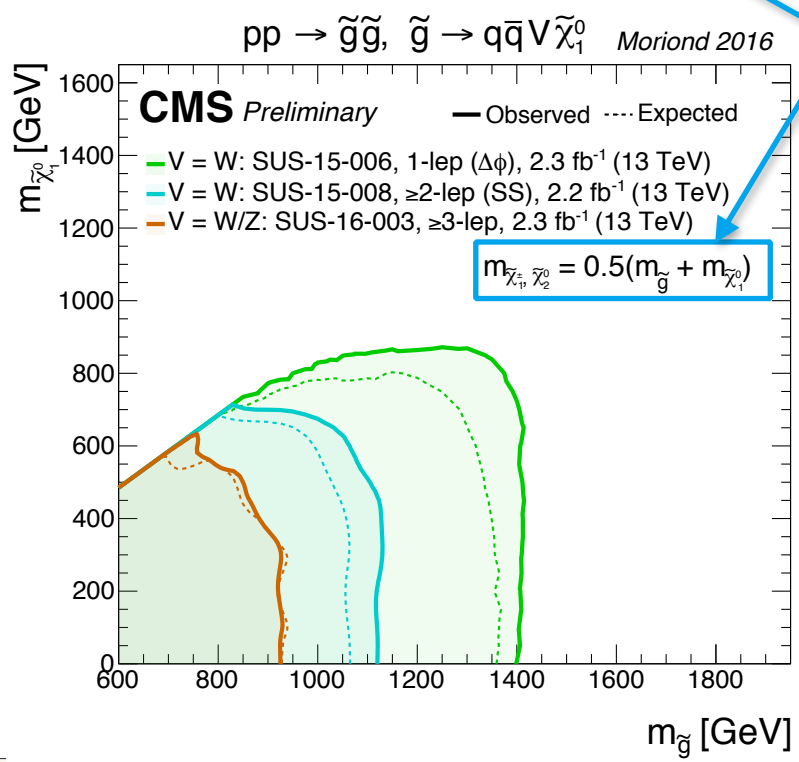

Compressed region well covered by 1ℓ-Δφ and SS analyses due to low MET cut

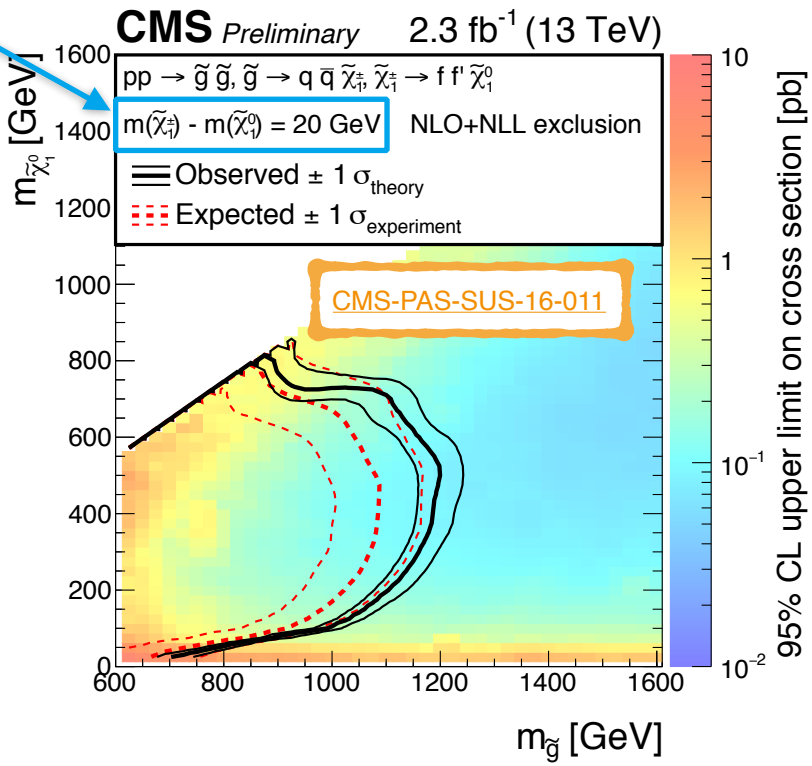
Light neutralino region pushed by 1ℓ searches with high $n_{jets}$

# Limit summary: T5qqqqVV

- 1$\ell$ analyses most sensitive and comparable to full hadronic
- Significant extension beyond 8TeV results
- Two mass splittings probed

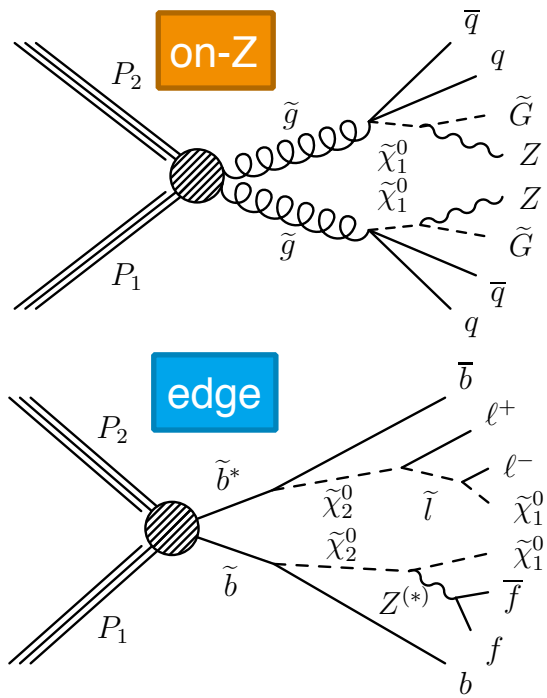


# SUS-15-011 (opposite-sign 2ℓ)

CMS-PAS-SUS-15-011




See also poster by Jan-Frederik

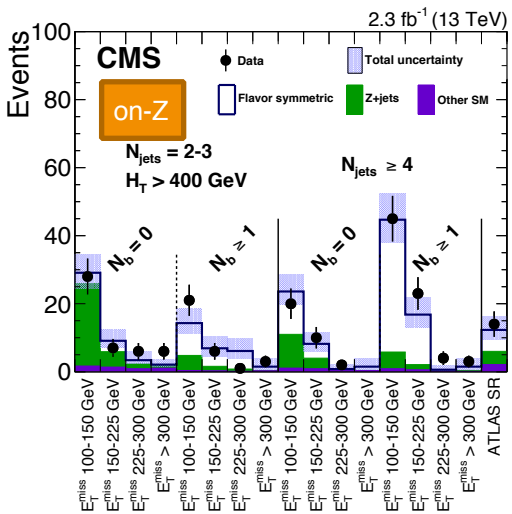
Preselection:

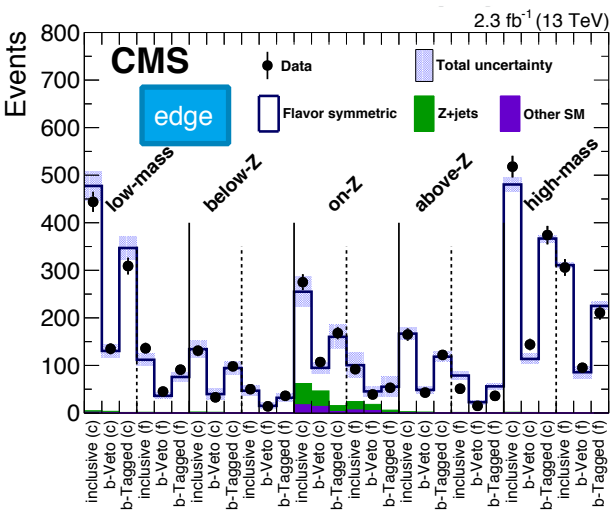
- OS same-flavour e/μ with $p_T > 20$ GeV
- $n_{jets} \geq 2$ ($p_T > 35$ GeV)
- MET > 100 GeV

Background estimation in categories:

- flavour-symmetric from OF control region
- Drell-Yan-like from data MET templates

**—> no excess found at 13TeV!**




Search categories for edge/on-Z binned in:

- MET, $H_T$, $n_{jets}$, $n_{btags}$ and $m_{\ell\ell}$
- including ATLAS-like SR (with 8TeV excess)

# Summary

- Gluino sensitivity strongly enhanced with 13 TeV
  - At least 30 times larger x-sec wrt 8 TeV
  - SM backgrounds increase < 4x
- Leptonic channels complement hadronic searches performed by CMS
  - less background, good acceptance
  - high discovery & measurement sensitivity
- No deviations from expectations in 2015 data

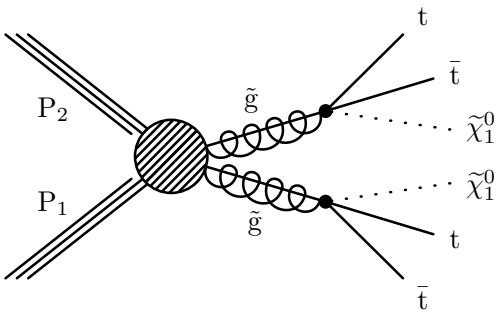
—> strong limits on simplified SUSY models surpassing 8 TeV results significantly

—> CMS ready for SUSY searches in 2016 data!

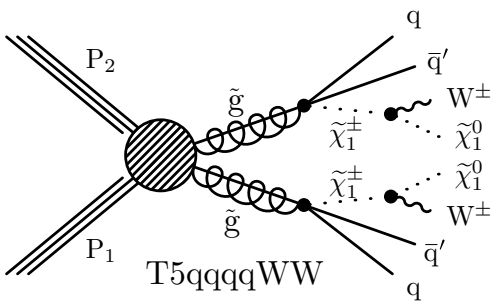
# BACKUP

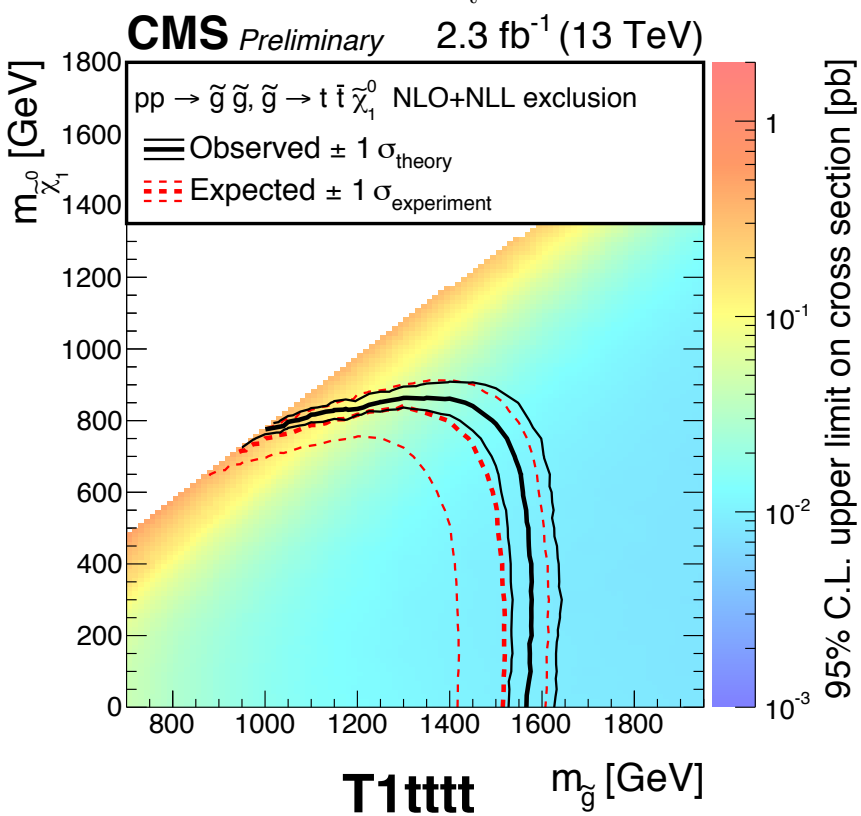
# SUS-15-006 (1ℓ, Δφ)

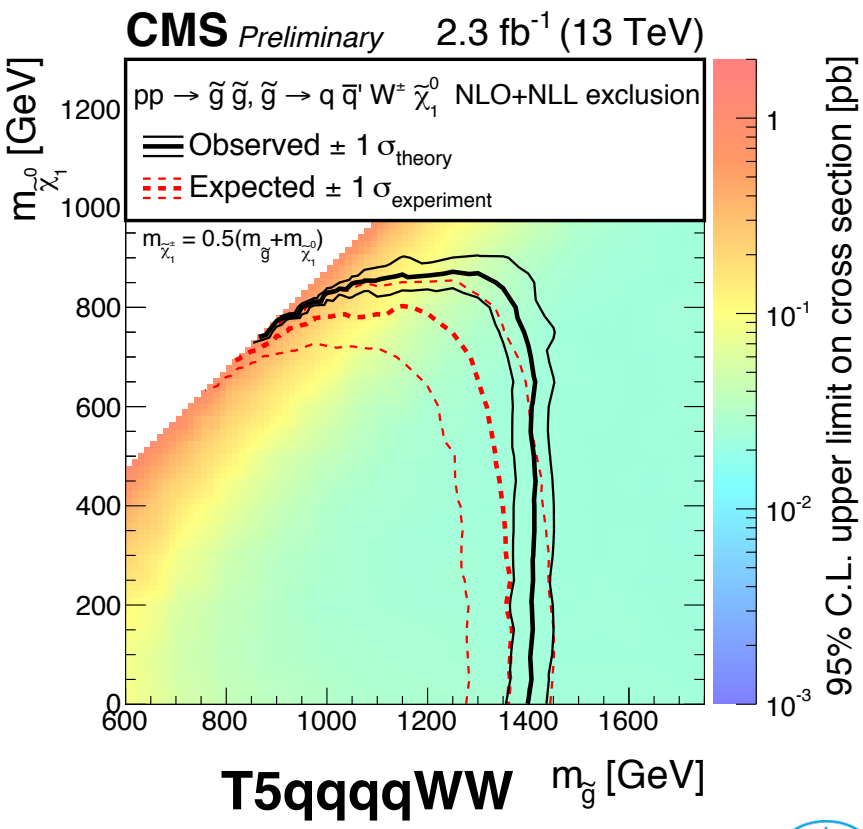
CMS-PAS-SUS-15-006




- With/without b-tag analyses allow two interpretations

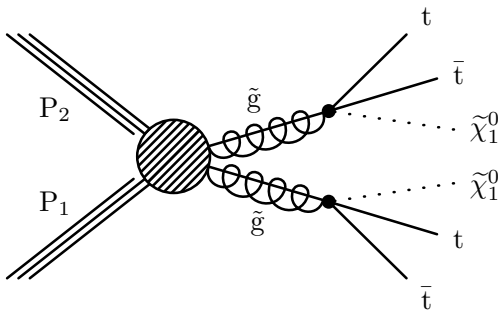


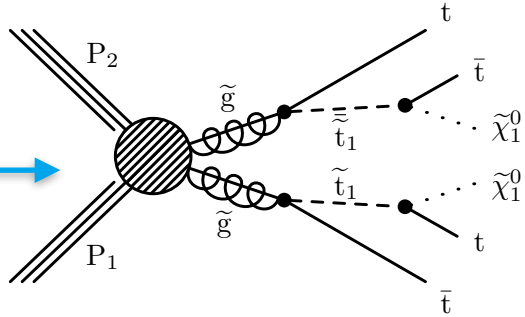



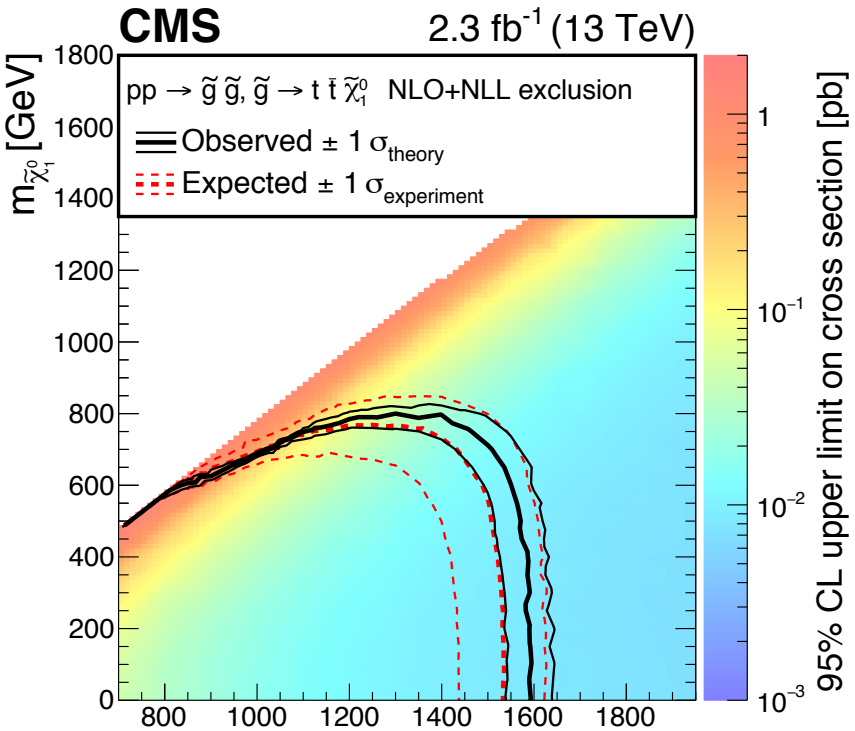
# SUS-15-007 (1ℓ, $M_J$)

arXiv:1605.04608

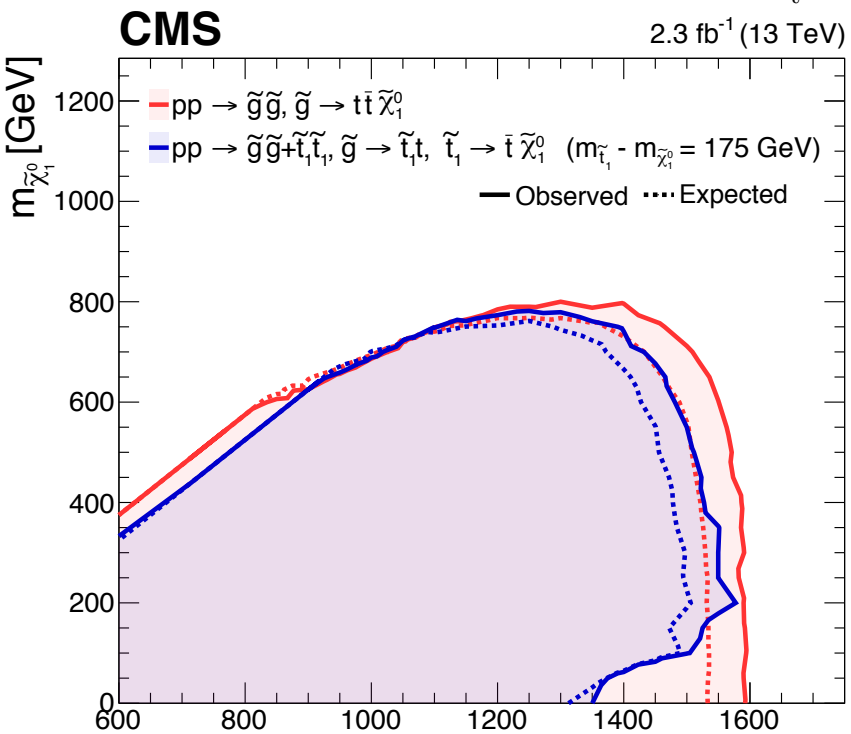



> Also interpreted with intermediate stop of top mass 175 GeV



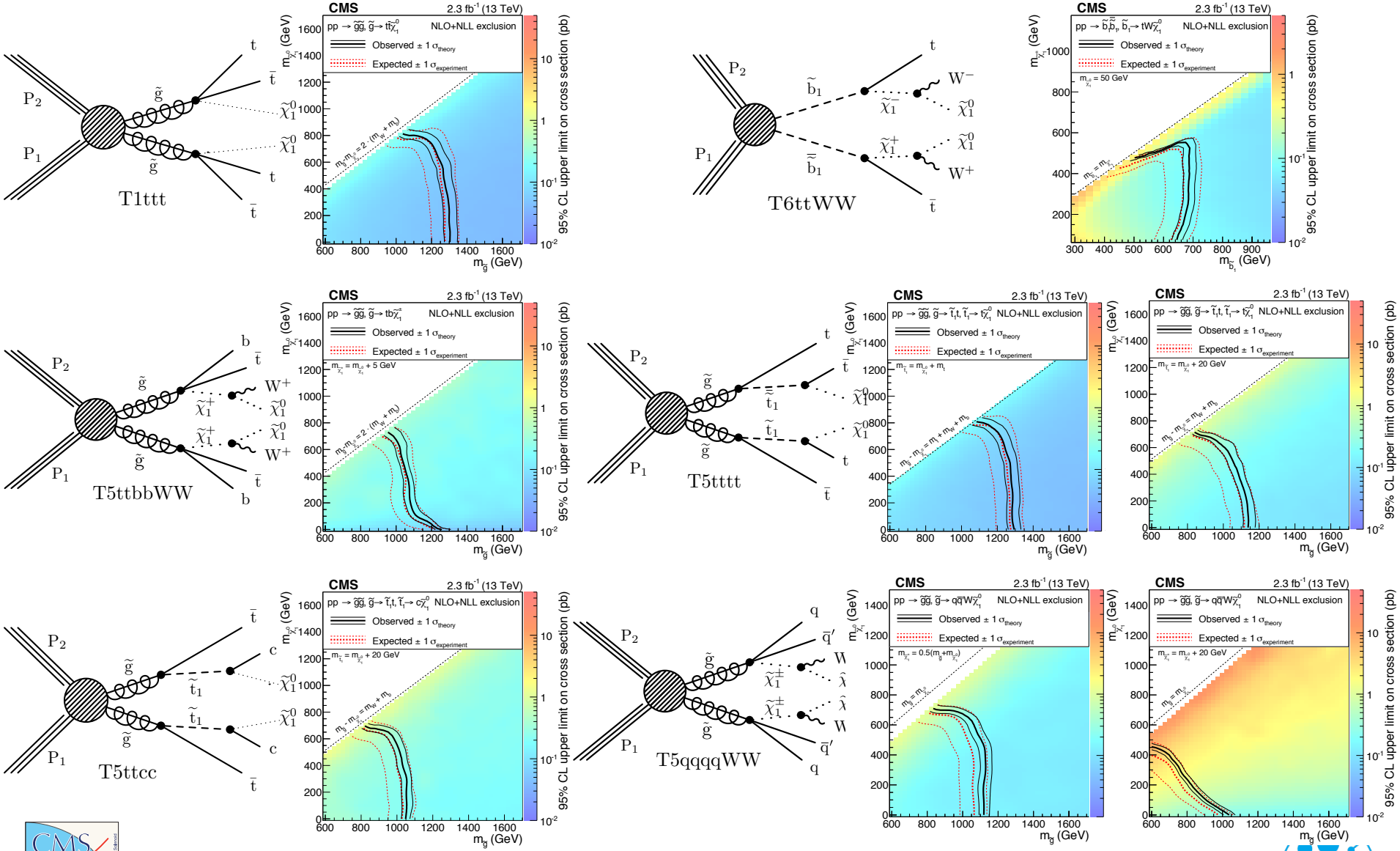

**T1tttt**




**T5tttt, $m_{stop}$ = 175GeV**

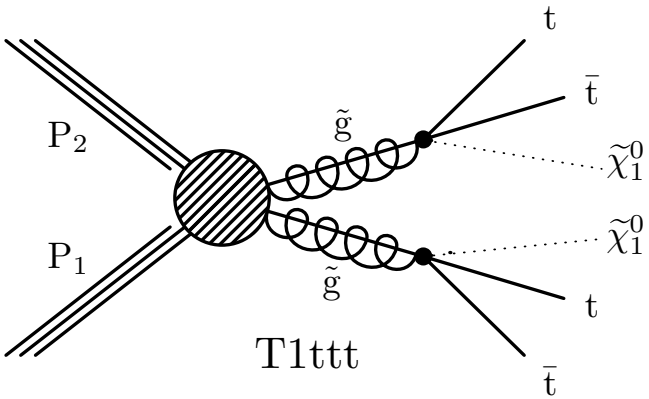
# SUS-15-008 (same-sign 2ℓ)

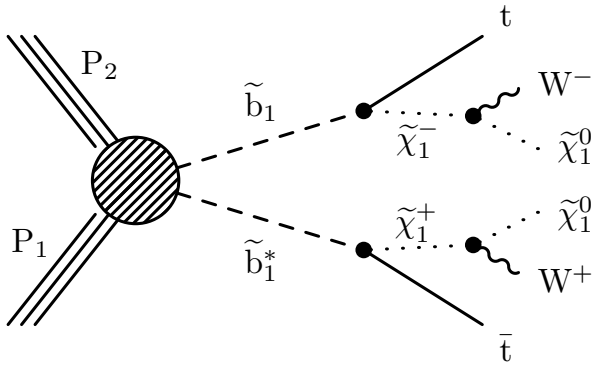
arXiv:1605.03171

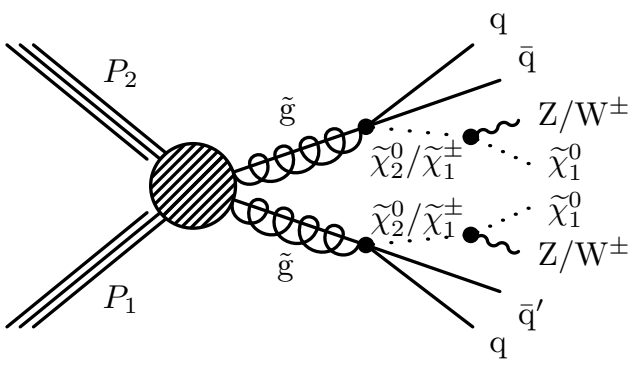


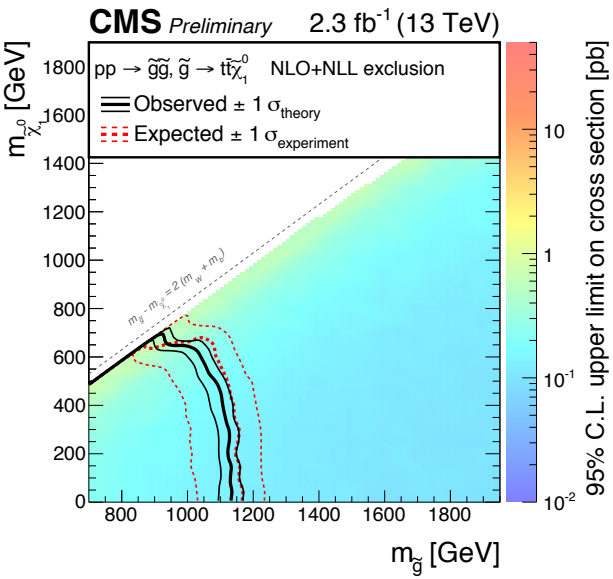
# SUS-16-003 (multileptons)

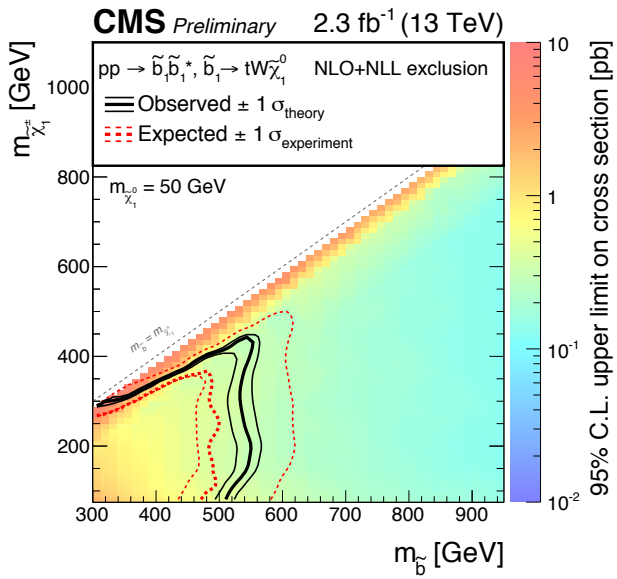
CMS-PAS-SUS-16-003

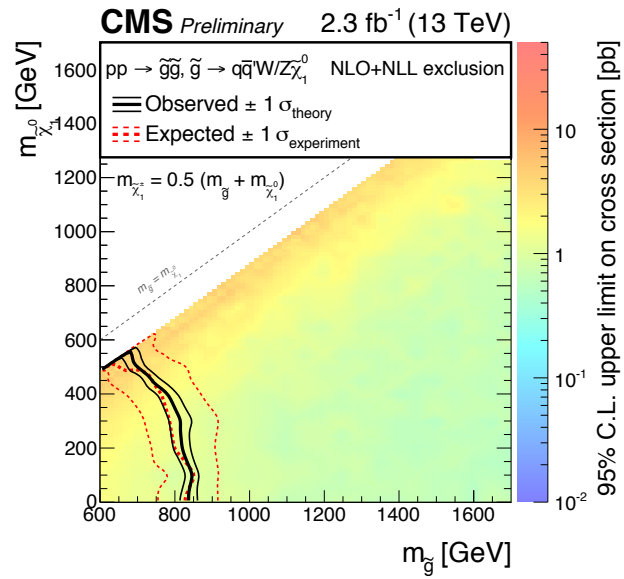


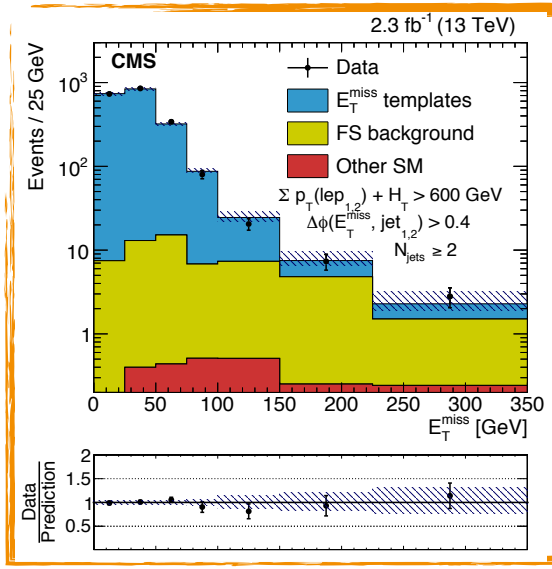



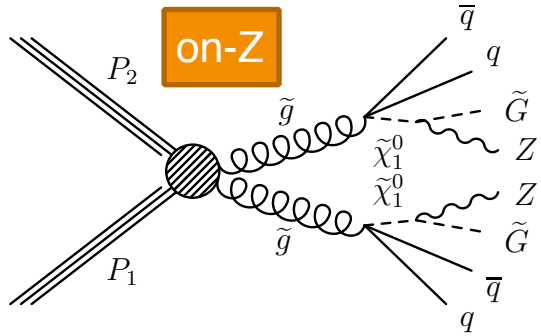



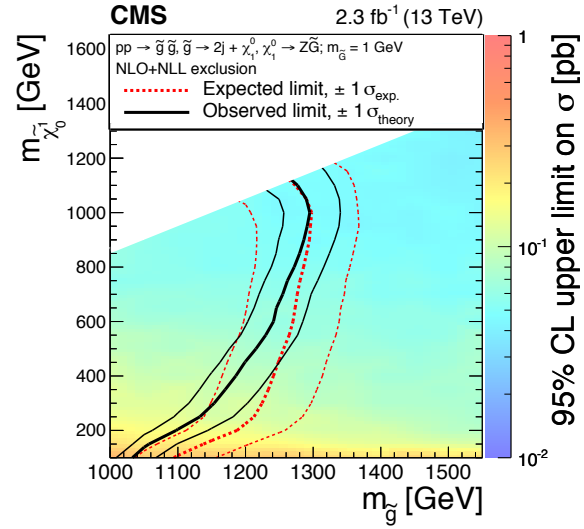
# SUS-15-011 (opposite-sign 2ℓ)

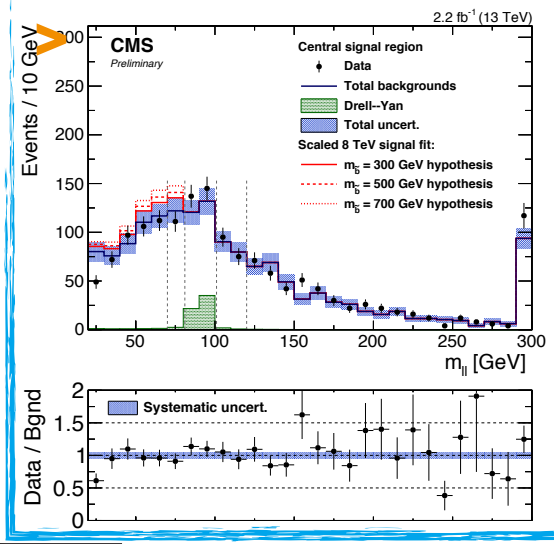
CMS-PAS-SUS-15-011

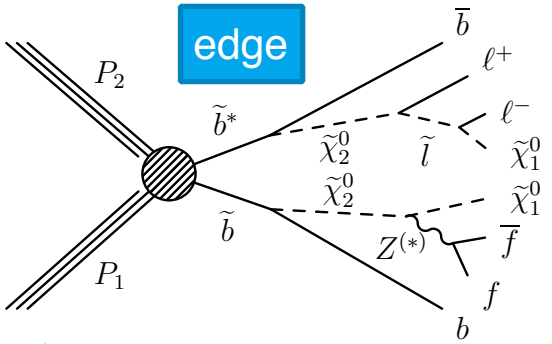



ATLAS-like SR




CMS 8TeV excess SR