# CMS Searches for SUSY with Leptons

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for the CMS Collaboration


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RUTGERS

# Overview

1. Introduction
2. SUS-13-002: Inclusive Multileptons
3. SUS-13-013: Same-sign Dileptons
4. SUS-14-014: Dileptons + Jets and MET
5. SUS-14-004: SUSY with 1 or 2 Photons
6. Conclusion

# Introduction

- CMS has broad sensitivity for models with leptons
- A whole lot of searches involving leptons based on the 2012 8TeV pp collision dataset (luminosity ~19.5/fb)
- Searches in this talk:
  - SUS-13-002: Inclusive Multileptons
  - SUS-13-014: Same-sign Dileptons
  - SUS-14-014: Dileptons + Jets and MET
  - SUS-14-004: SUSY with 1 or 2 Photons (new!)
- Focusing on results, given the time constraint

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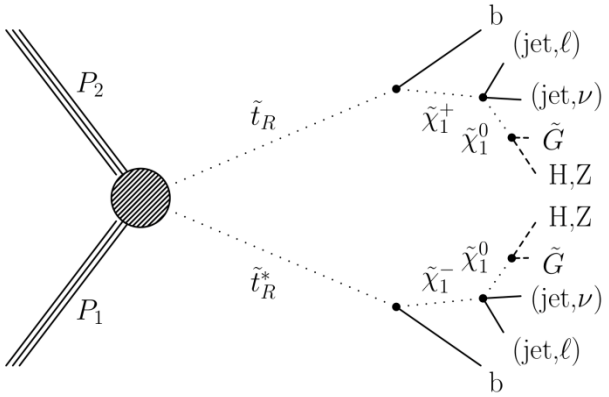
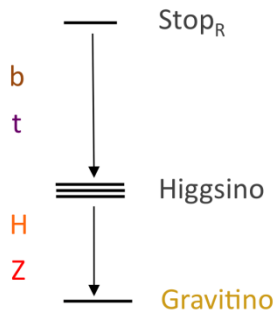
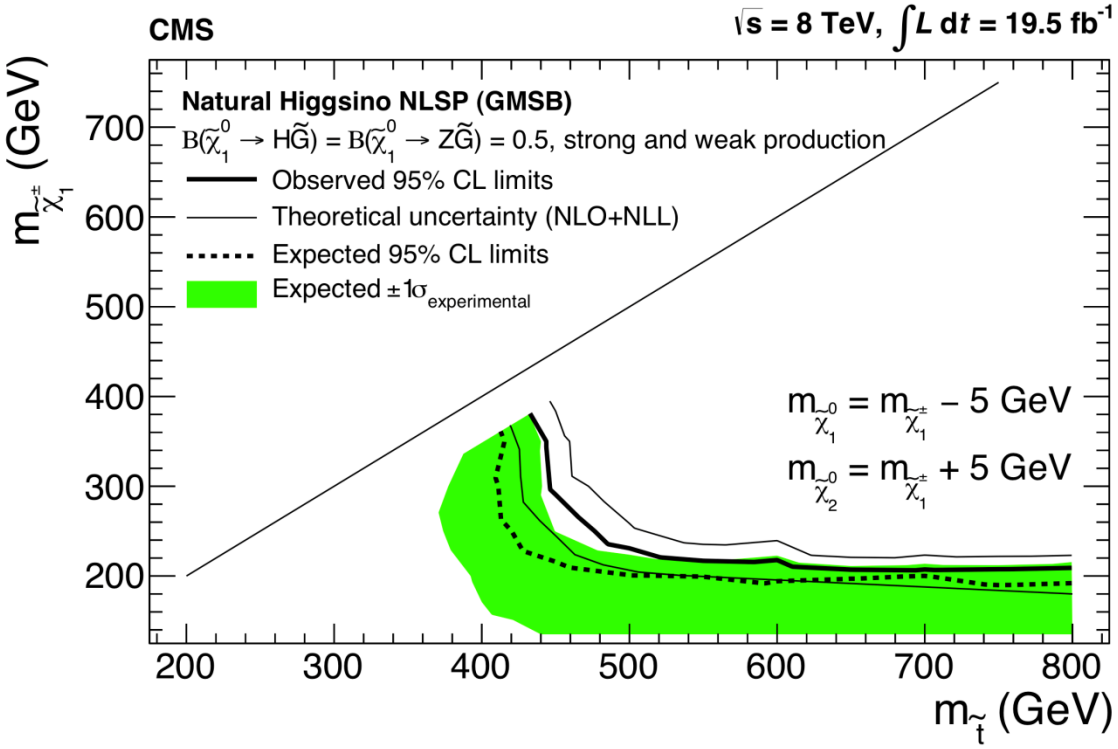
# SUS-13-002: Inclusive Multileptons

- Vast diversity in possible signal signatures → looking in a large number of exclusive channels
  - Are there OSSF pairs ($e^+e^-$, $\mu^+\mu^-$)?
  - Is there a Z candidate (OSSF mass on Z peak)?
  - Are there hadronic taus?
  - Are there b-tagged jets?
  - What is the total MET, $H_T$, and $S_T$ of the event?
- Require $p_T \geq 10$ GeV, but leading lepton above 20 GeV
- Backgrounds based both on MC and on data-driven methods

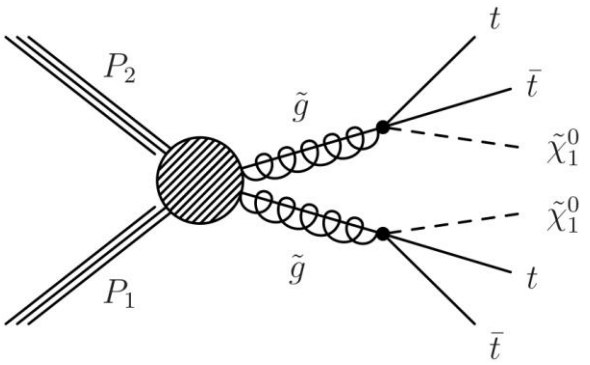
# SUS-13-002: Higgsino (fixed BR)

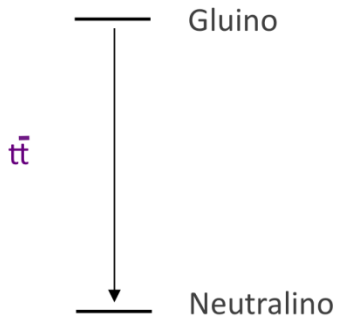


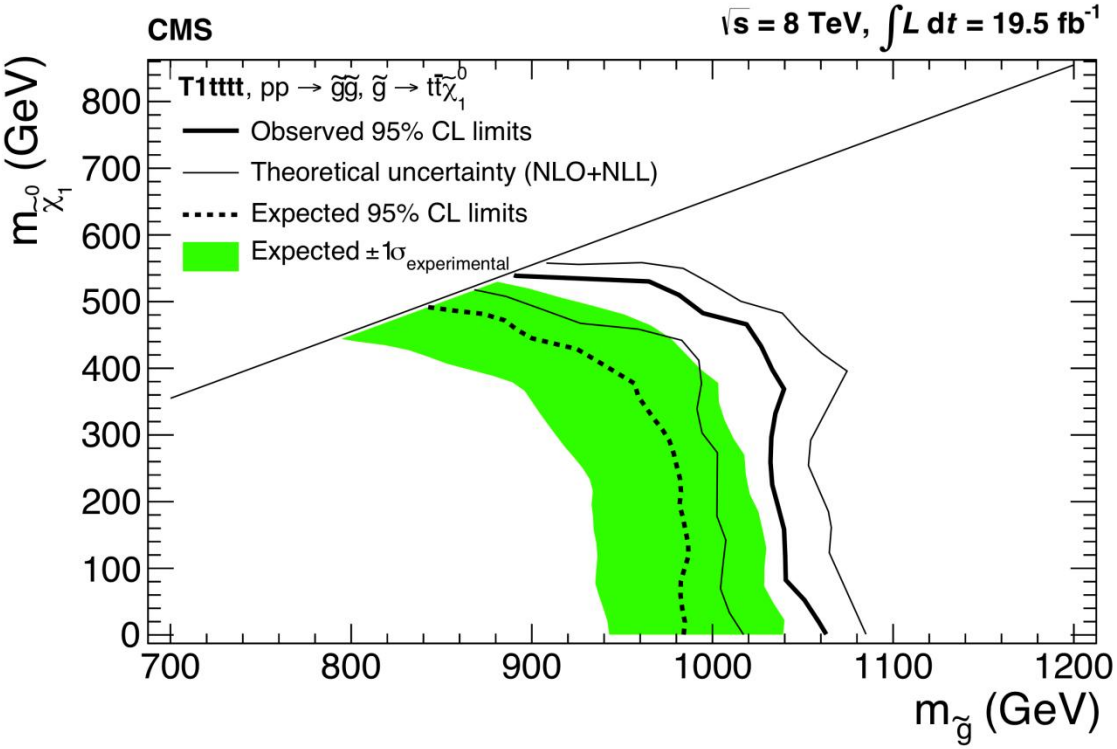



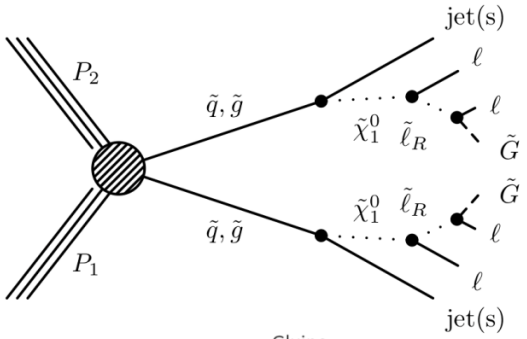
# SUS-13-002: T1tttt

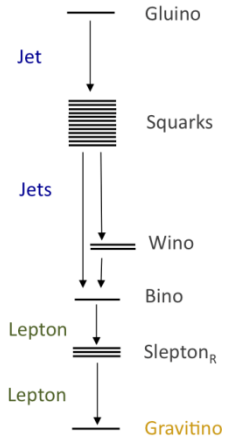


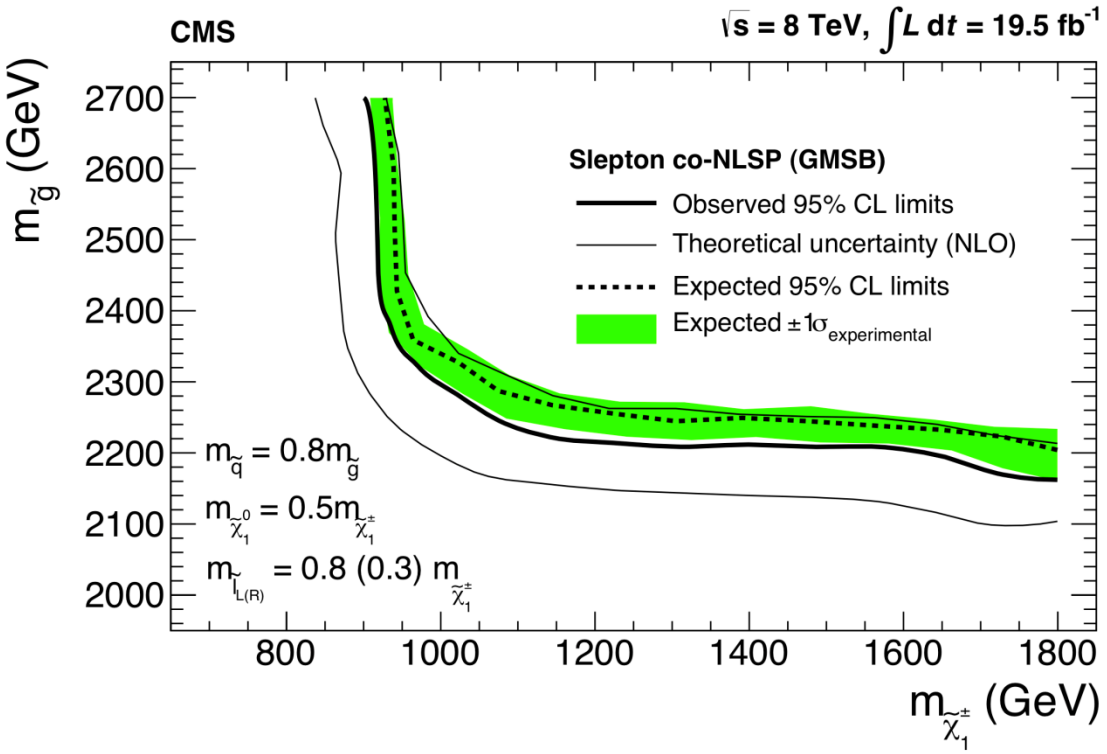



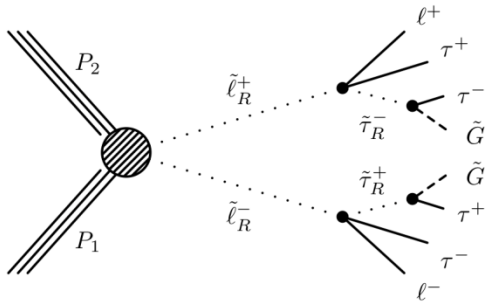
# SUS-13-002: Slepton co-NLSP

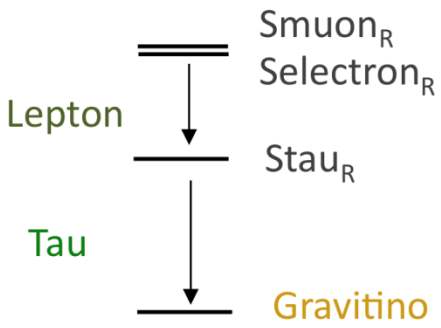


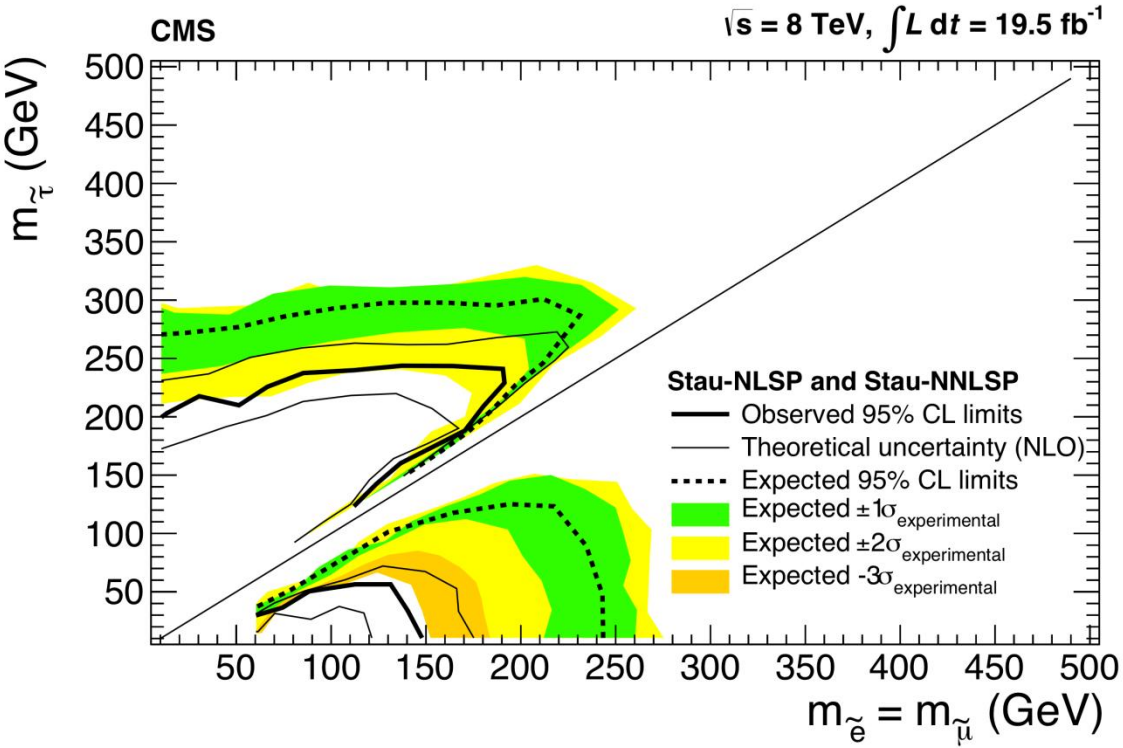



# SUS-13-002: stau-(N)NLSP

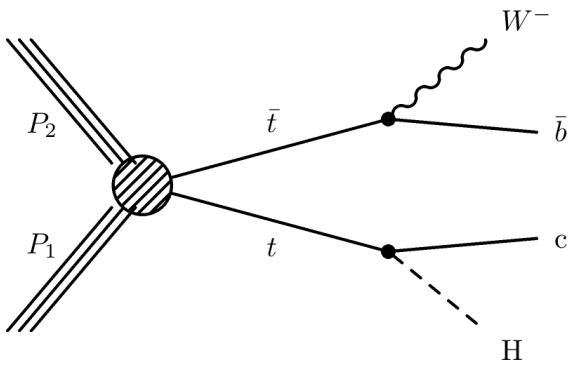


# SUS-13-002: t → cH

- Flavor-changing neutral current t → cH negligible in SM
- Investigated pp → ttbar → (bW)(cH), with SM Higgs BRs
- Limit both on BR(t → cH) and on Yukawa coupling




| Higgs boson decay mode | | Upper limits on $\mathcal{B}(t \to cH)$ Obs. | Exp. | $1\sigma$ range |
|---|---|---|---|---|
| $\mathcal{B}(H \to WW^*)$ | $= 23.1\%$ | 1.6 % | 1.6% | (1.0–2.2)% |
| $\mathcal{B}(H \to \tau\tau)$ | $= 6.2\%$ | 7.01% | 5.0 % | (3.5–7.7)% |
| $\mathcal{B}(H \to ZZ^*)$ | $= 2.9\%$ | 5.3% | 4.11% | (2.9–6.5)% |
| Combined | | 1.3% | 1.2% | (0.9–1.7)% |

$$\sqrt{|\lambda^{H}_{tc}|^2 + |\lambda^{H}_{ct}|^2} < 0.21$$ ~ 2 sqrt(BR)

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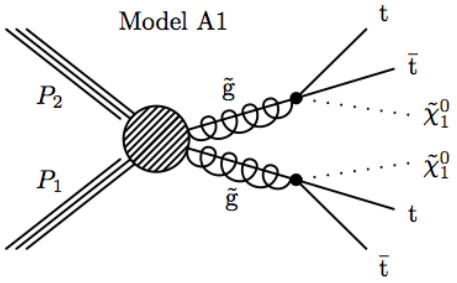
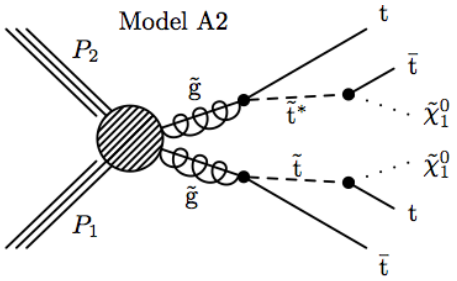
# SUS-13-013: Same-sign Dileptons

- Search using same-sign dilepton events
- Multiple channels defined by
  - MET
  - $H_T$
  - Number of jets and b-tags
  - Lepton $p_T$ (20 GeV for high $p_T$ vs. 10 GeV for low $p_T$ analysis)
- Backgrounds:
  - Non-prompt: using tight-loose method binned in $p_T$ and $\eta$
  - Rare processes from MC
  - Electron charge misidentification based on SS vs. OS study on Z

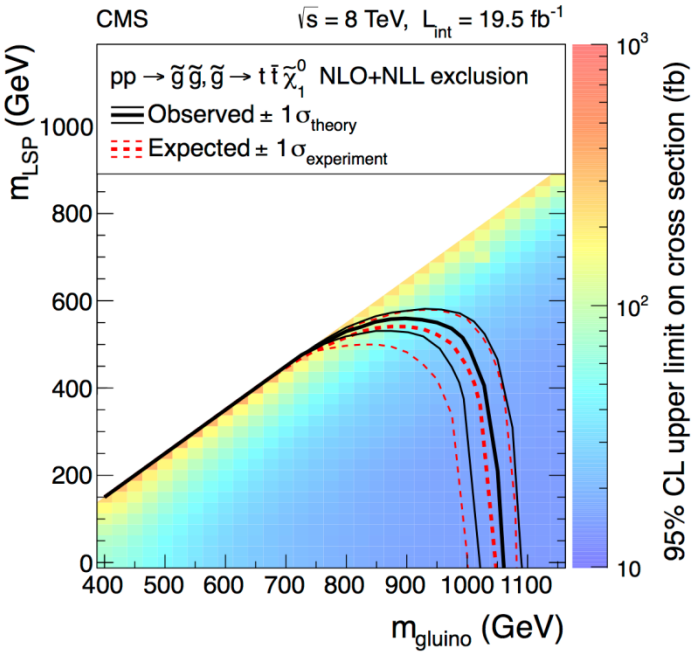
# SUS-13-013: Models A1, A2

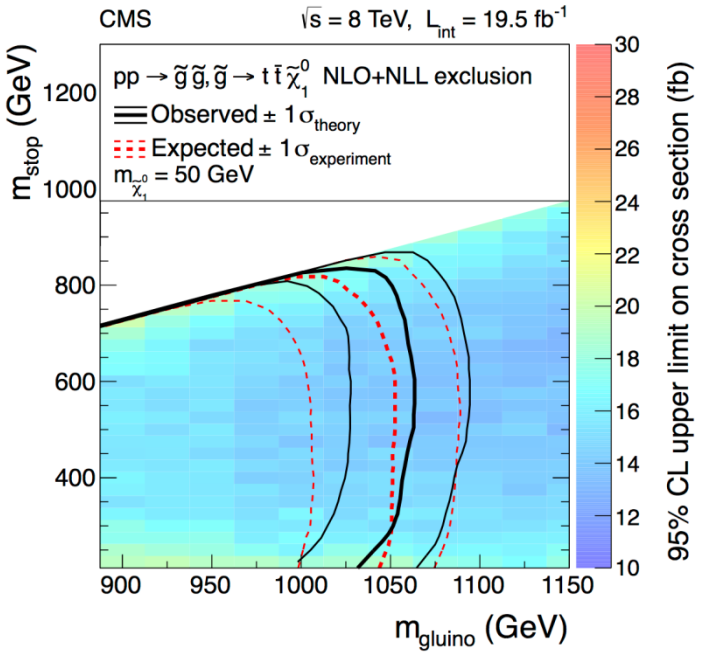



3-body decay

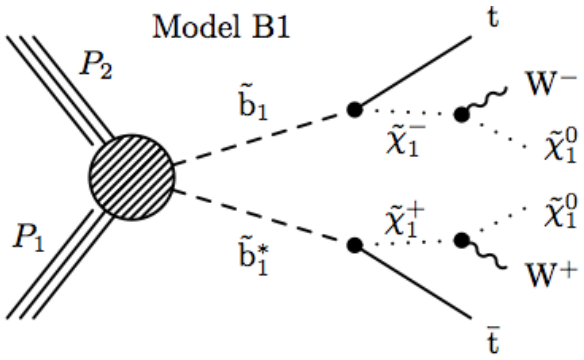


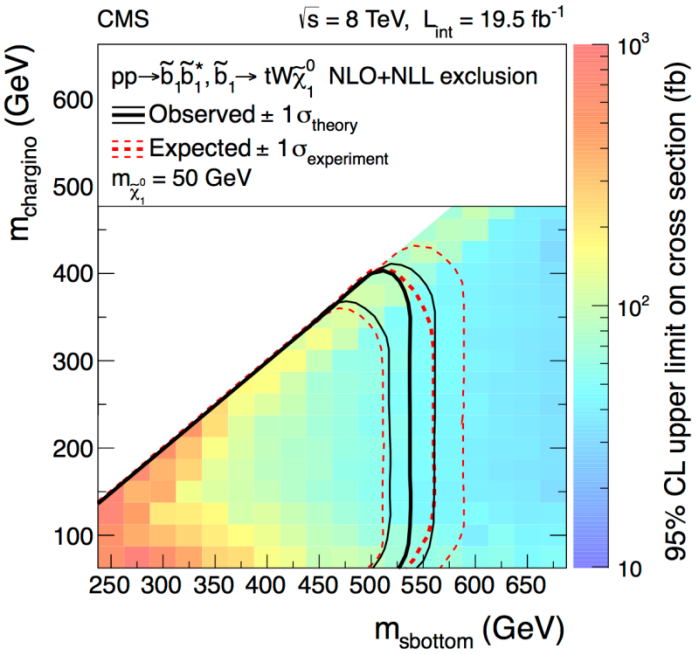

on-shell stop



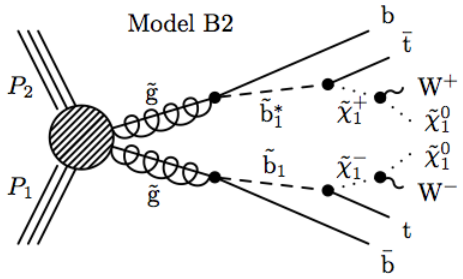
# SUS-13-013: Model B1

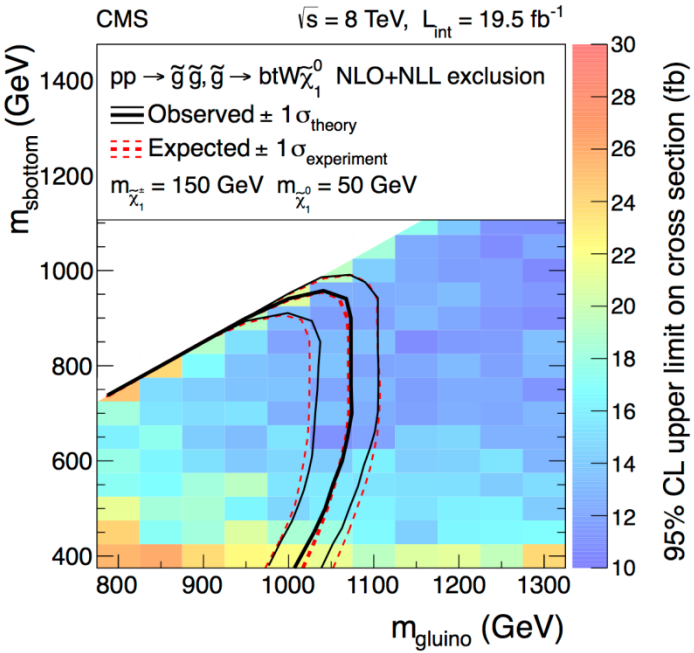


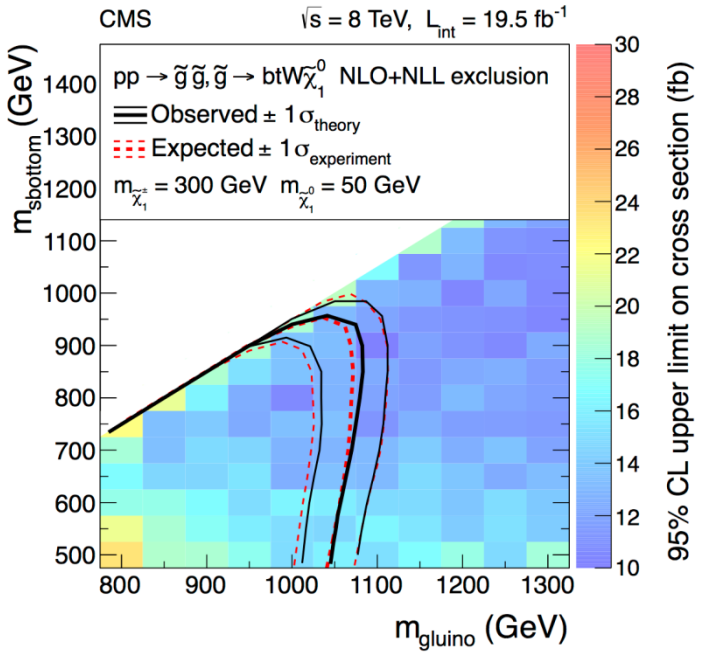




- Also interpretation with varying neutralino mass
  - See backup

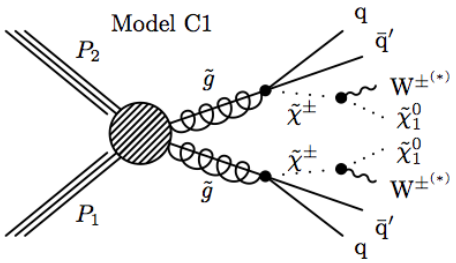
# SUS-13-013: Model B2

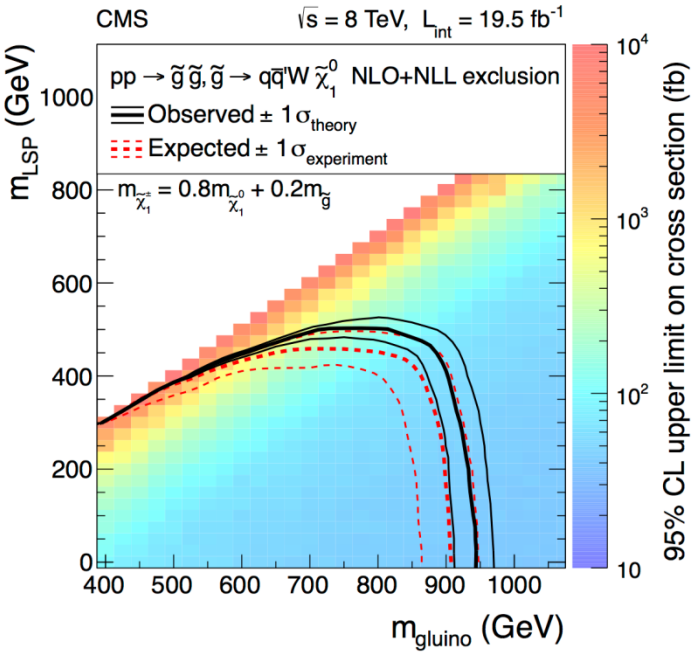


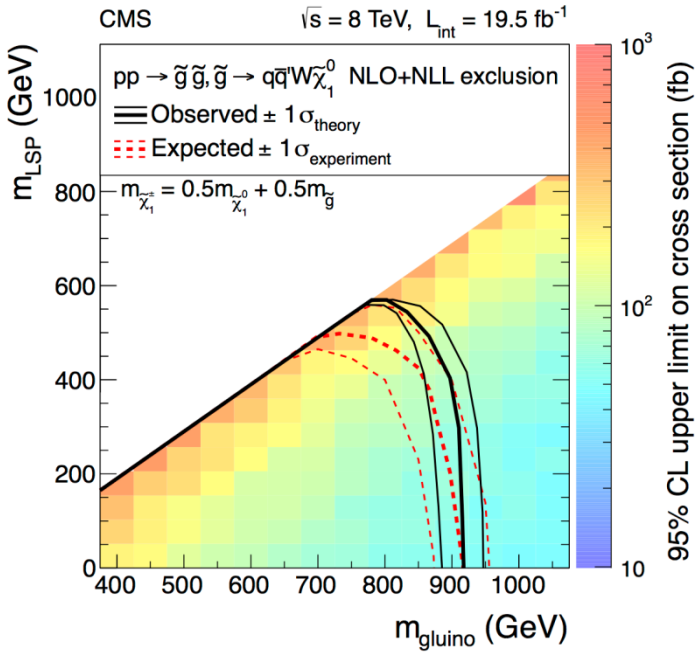



# SUS-13-013: Model C1



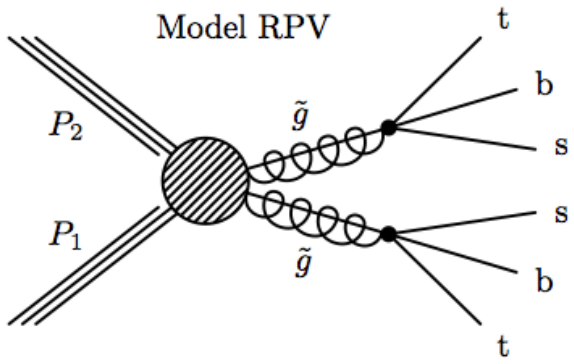



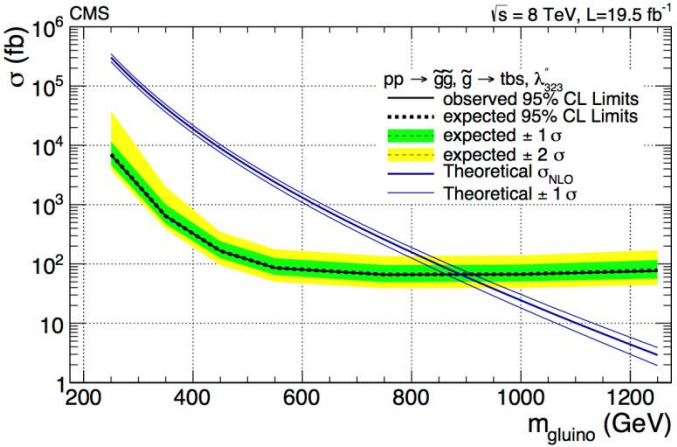

off-shell W




on-shell W

# SUS-13-013: RPV simplified model




- Produces same-sign dileptons from W's 50% of the time
- Comes with 2 b-jets

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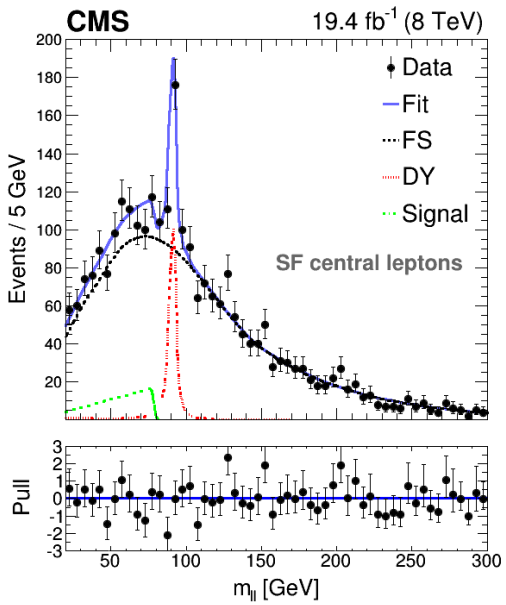
# SUS-14-014: Dilepton + jets and MET

- Two components:
  - Search for an edge in the opposite-sign same-flavor mass distribution (with fit method and with below/on/above Z counting experiment)
  - Dedicated search for final states on Z (counting experiment)
- Backgrounds estimated using data-driven methods:
  - Flavor-symmetric (ttbar-dominated): OF as often as SF pairs
    - Determined from opposite-flavor control sample (with scale factor)
    - Also includes WW, $Z \rightarrow \tau\tau$, tW
  - DY is second largest background
    - Determined using kinematic fit and recoil method

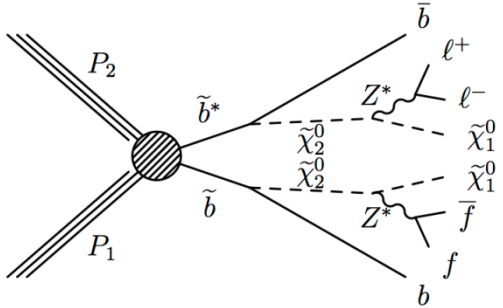
# SUS-14-014: Fixed-edge Scenario

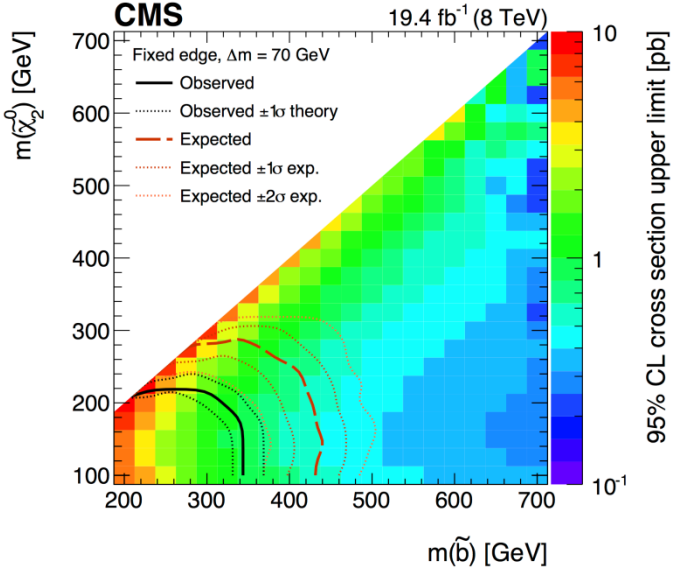



- Dilepton OSSF mass edge at 78.7±1.4 GeV
  - p-vaue: 0.009, corresponding to an excess of 2.4 sigma
  - Cross-checks with different fitting and binning approaches
- Excess is diminished when applying b-tag veto

# SUS-14-014: Fixed-edge Scenario

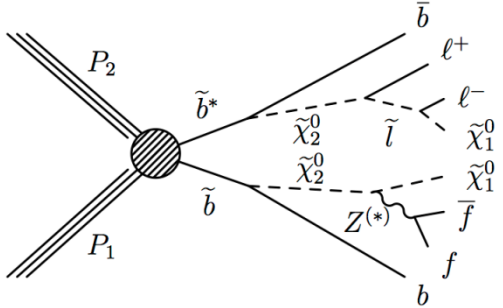
- Excess suggests sbottom production
  - $\Delta m(\chi_1,\chi_2) = 70$ GeV $\rightarrow$ edge
- Based on counting experiment only
  - Fit would be more model-specific

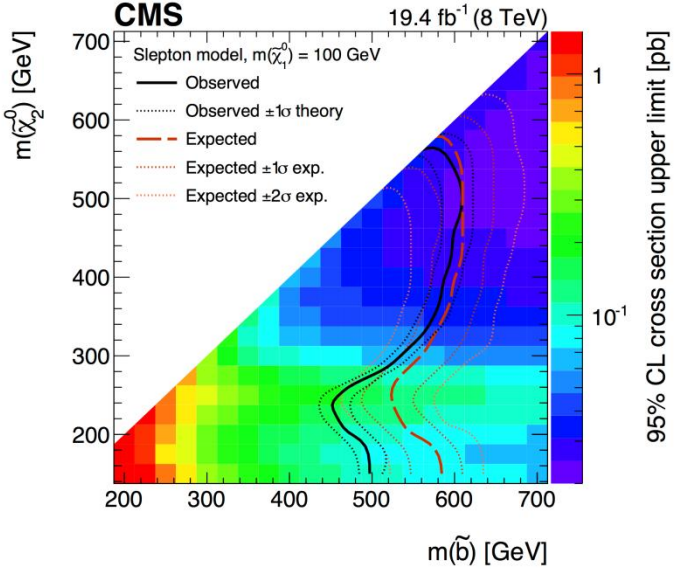


# SUS-14-014: Slepton-edge Scenario

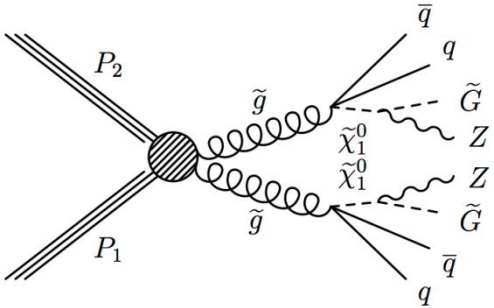
- Higher branching ratio to dileptons
- $\Delta m(\chi_1,\chi_2)$ left as free parameter
- Based on counting experiment only
  - Shape due to gaps in $m_{OSSF}$ binning (can coincide with edge peak)

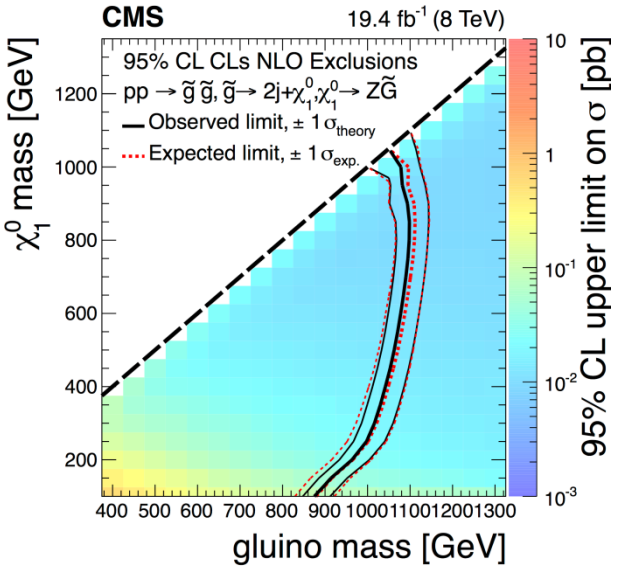


# SUS-14-014: GMSB Scenario

- Based on dedicated on-Z regions
- High hadronic activity
  - Using bins with at least 3 jets and MET > 100 GeV



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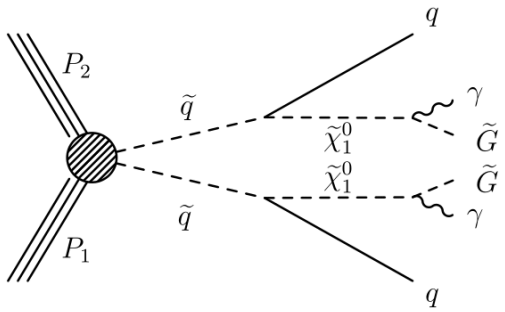
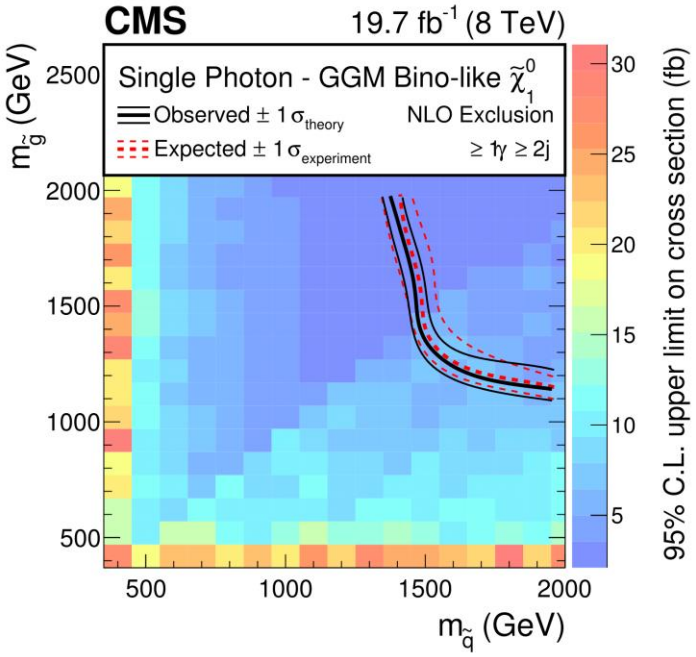
# SUS-14-004: SUSY with Photons

- Analysis split in two parts:
  - At least 1 photon, at least 2 jets, high MET
    - Dominant background (multijet) estimated using tight-loose method
    - ISR/FSR via MC
  - At least 2 photons, at least 1 jet, using Razor variables
    - Razor background shape determined via fit in control region
- Both analyses uses data-driven background estimates
- Interpretations both in gauge-mediated (GMSB) and in simplified models

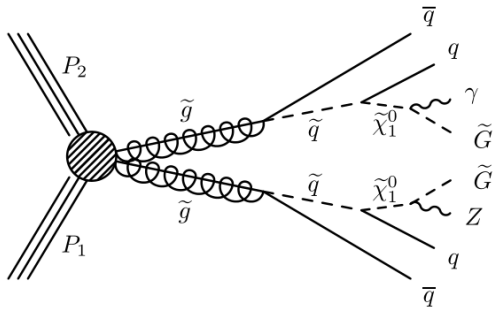
# SUS-14-004: Single photon, GGMbino

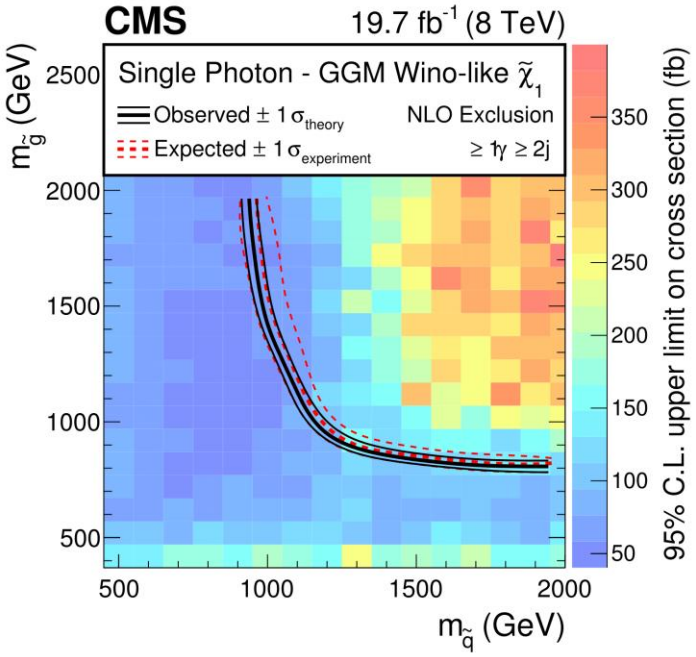



- $m(\chi_1^0)$ = 375 GeV
  - BR to photon: about 80%

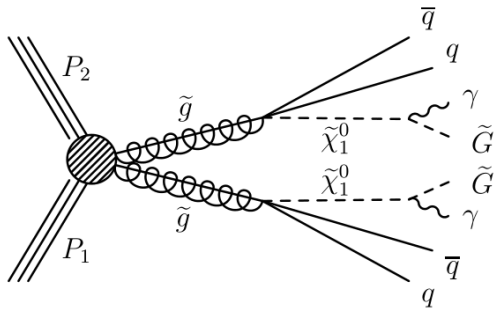
# SUS-14-004: Single photon, GGMwino

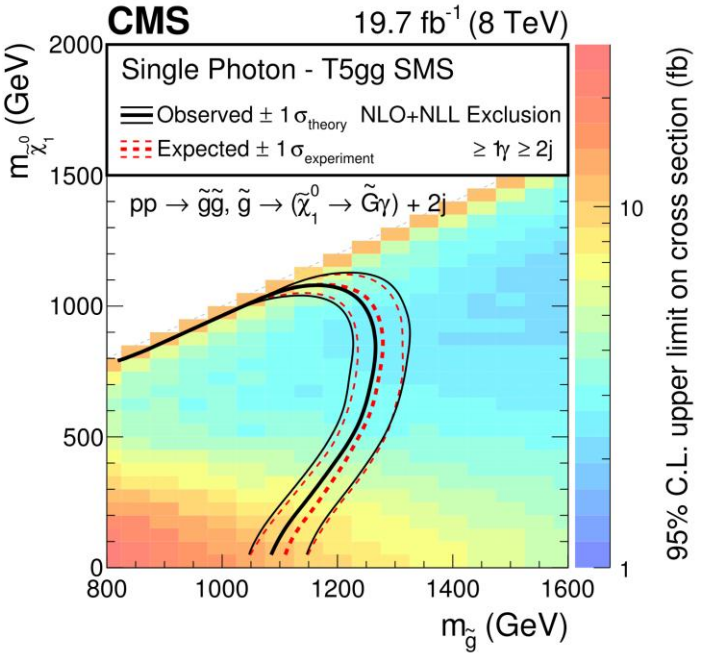



- Same as before, but wino-like
  - $m(\chi_1^0) = m(\chi_1^{\pm}) = 375$ GeV

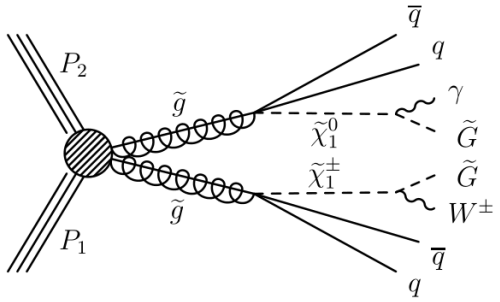
# SUS-14-004: Single photon, T5gg

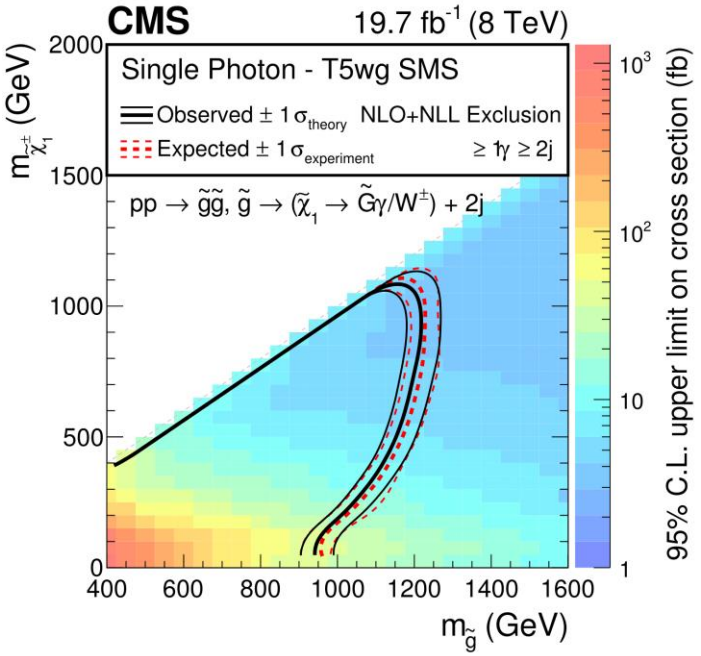



- Three-body decays
  - All BR's: 100%

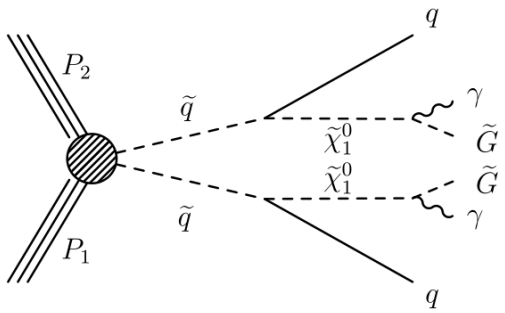
# SUS-14-004: Single photon, T5wg

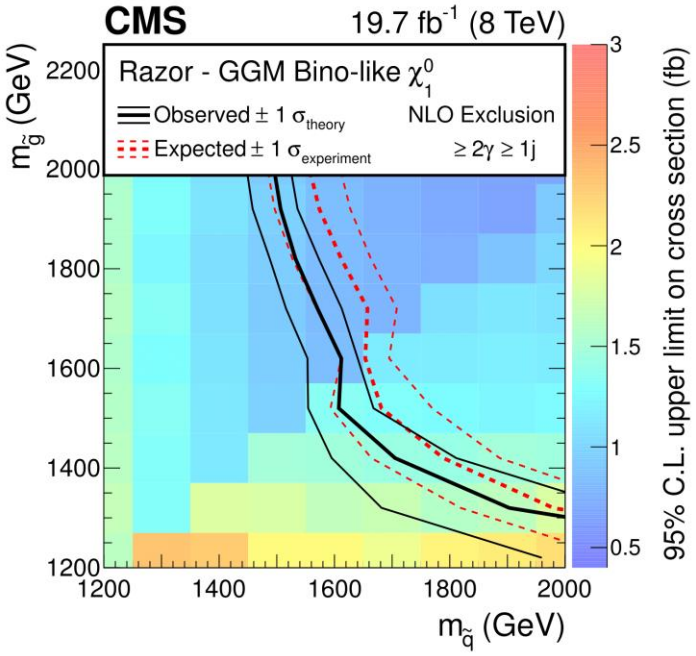



- Second leg has a chargino
  - All BR's: 100%

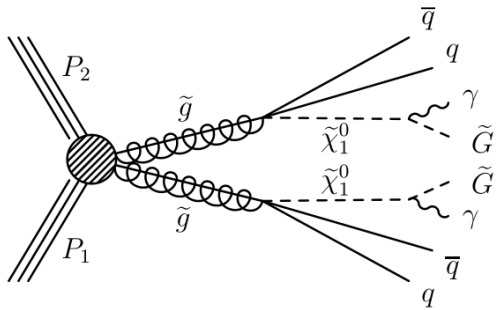
# SUS-14-004: Diphoton, GGMbino

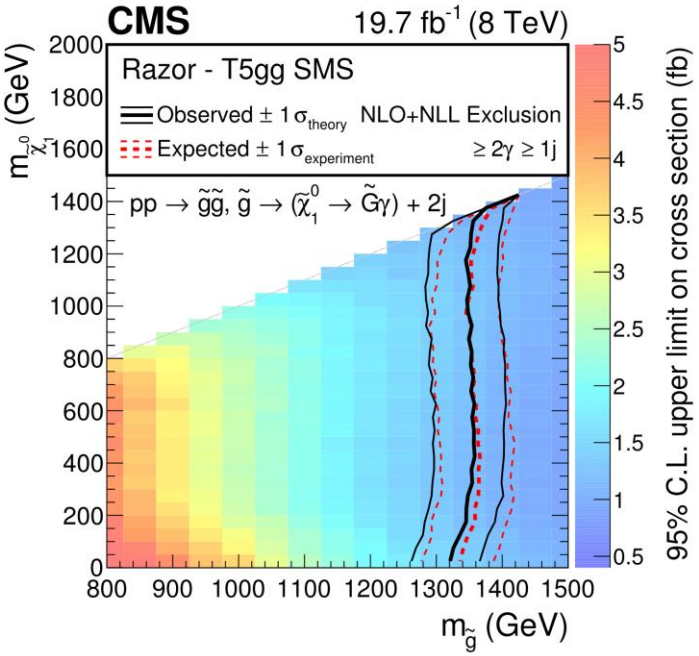



- Slightly better than single-photon
  - Due to $H_T$ requirement in single-photon trigger

# SUS-14-004: Diphoton, T5gg



# Overview

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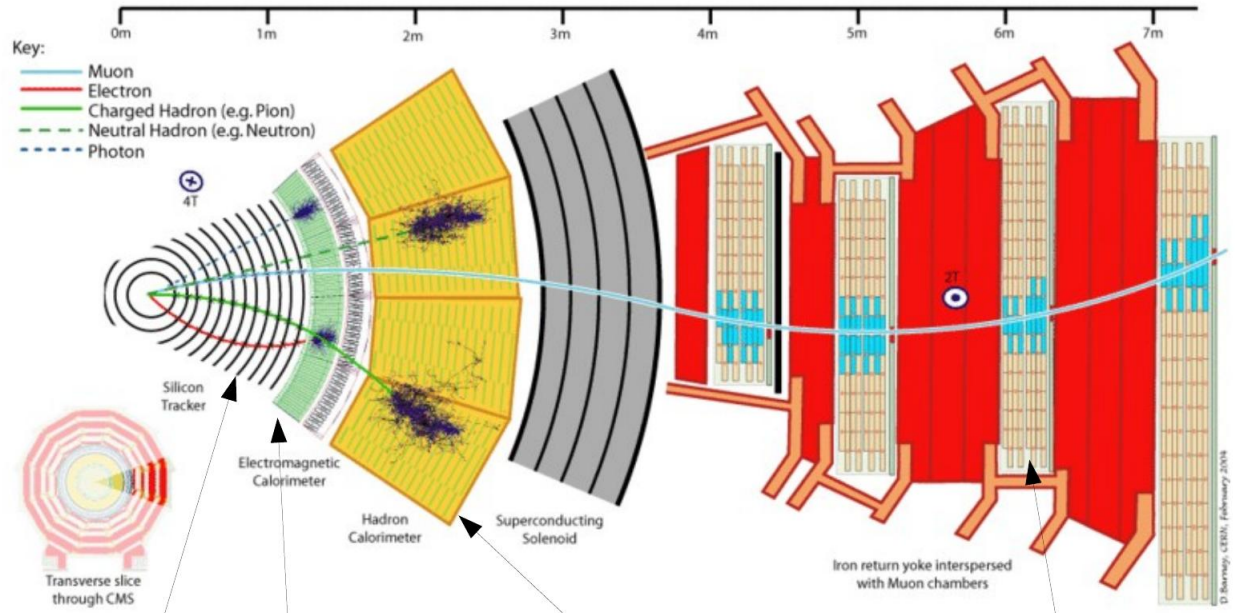
# Conclusion

- SUSY searches with leptons in 2012 CMS data at 8 TeV
- Highlights:
  - Multilepton search with lots of bins and interpretations
  - Same-sign and opposite-sign dilepton searches
  - New searches with photons and jets
- Generally good agreement, but some interesting features
  - Excluded regions of parameter space
- 13 TeV updates with increased sensitivity coming up!

# Backup

# Detector



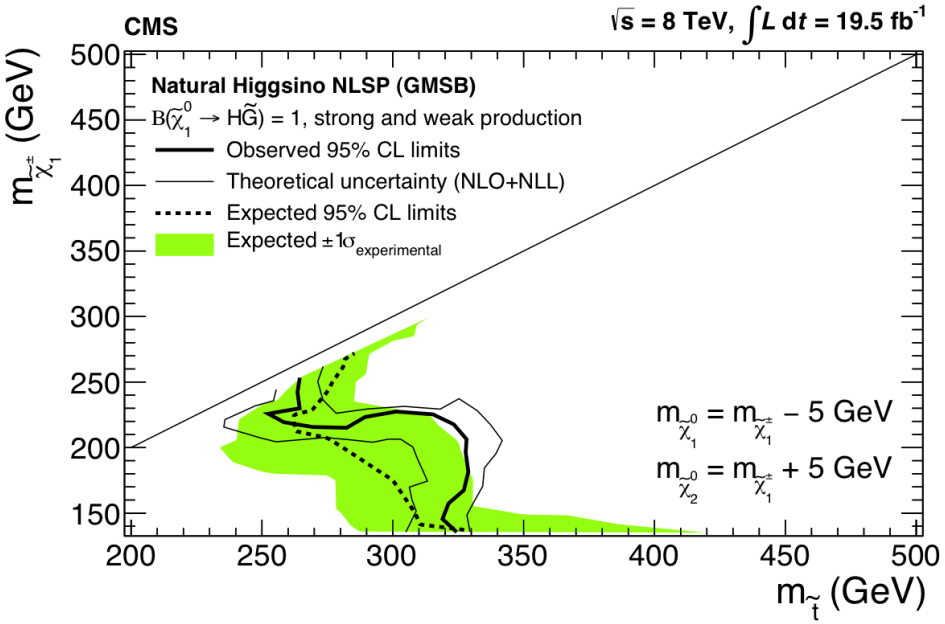

**Tracker:** Electrons, Muons, Charged Hadrons

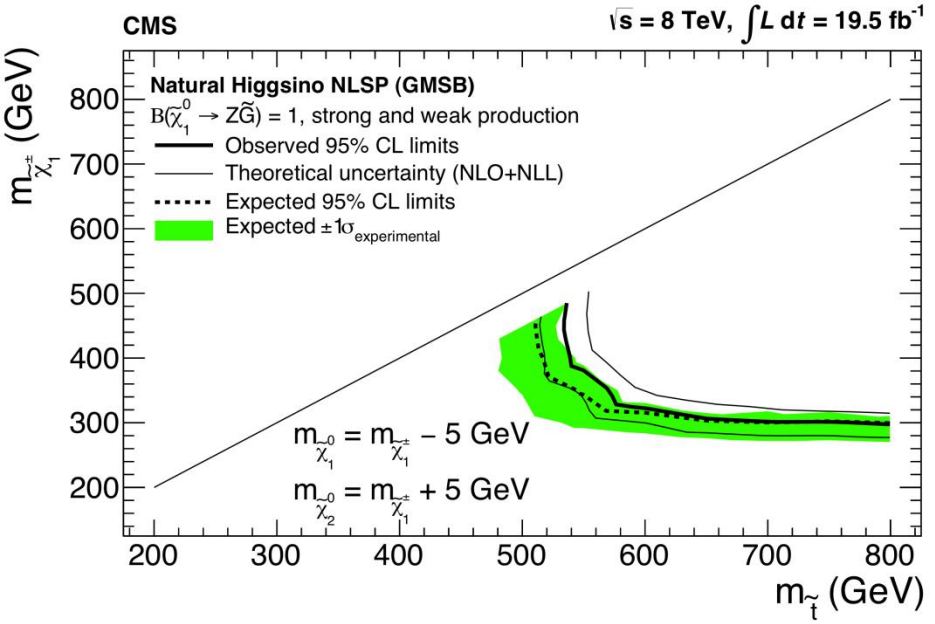
**Electromagnetic Calorimeter:** Electrons, Photons

**Hadronic Calorimeter:** Hadrons (neutral & charged)

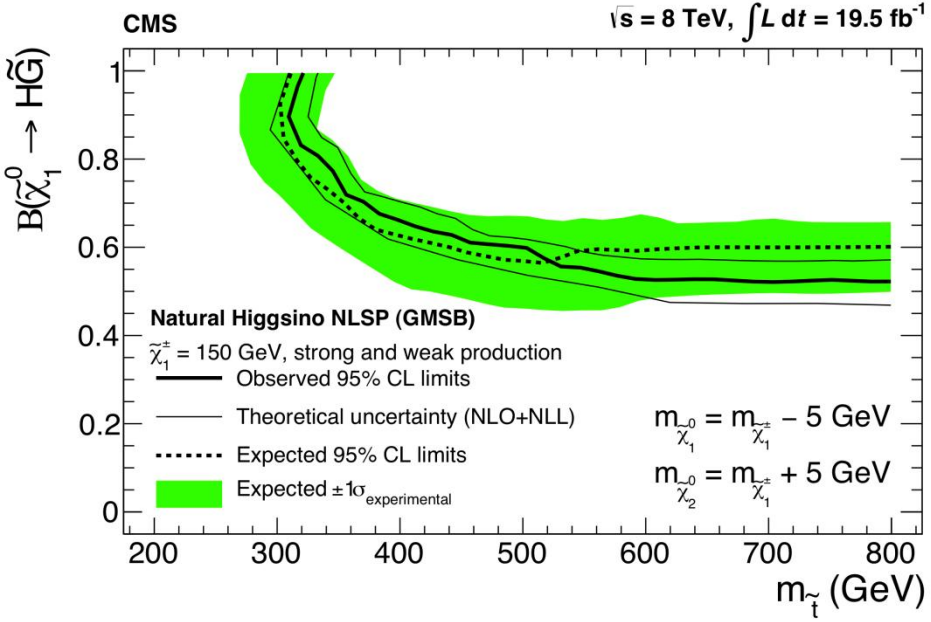
**Muon Chambers:** Muons

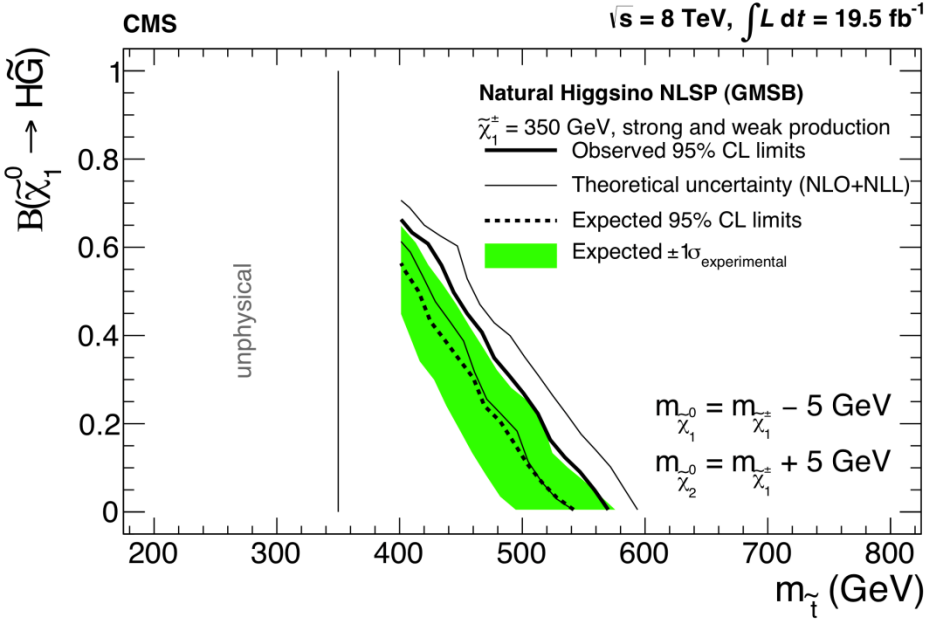
# SUS-13-002: Higgsino (fixed BR)



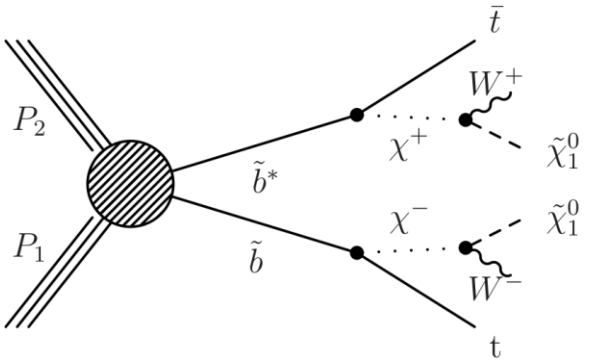



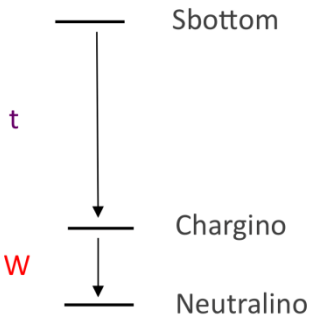
# SUS-13-002: Higgsino (floating BR)

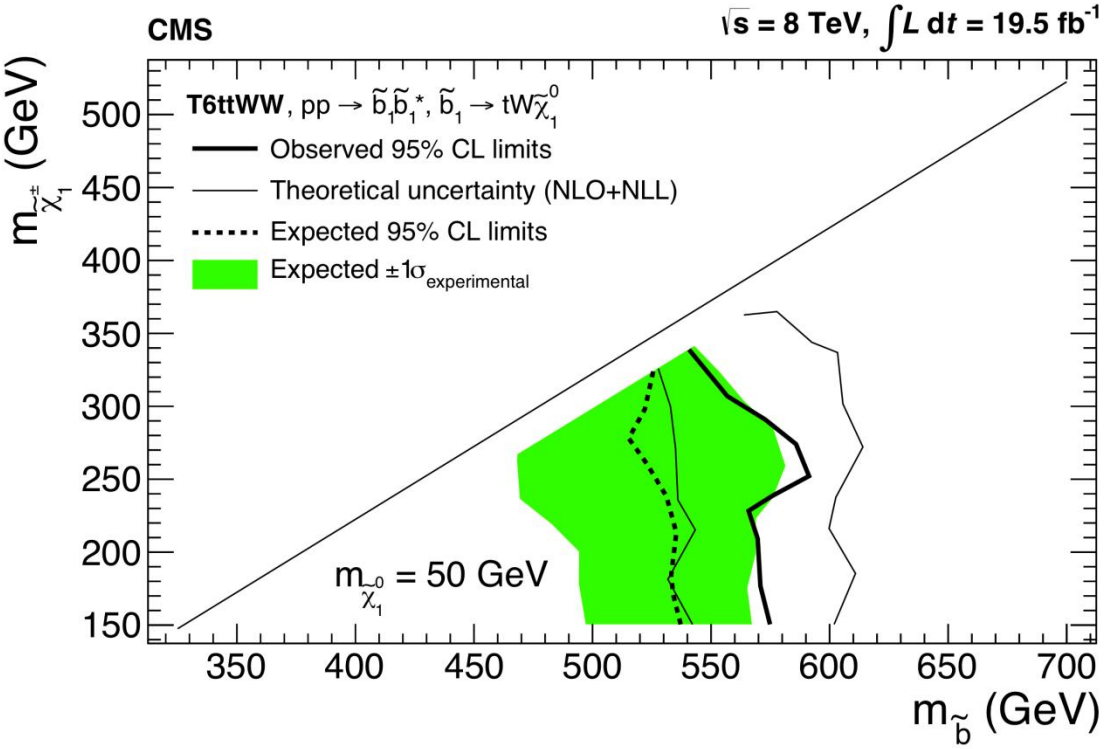


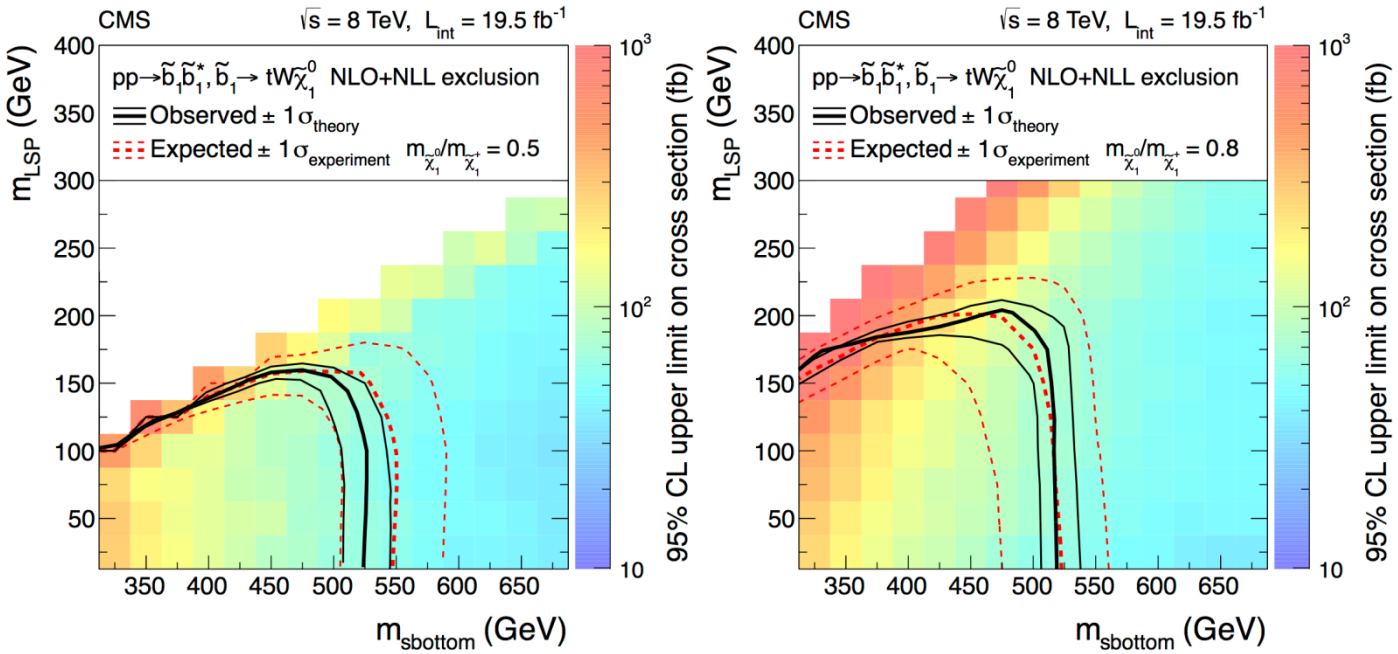
# SUS-13-002: T6ttWW



# SUS-13-013: Model B1 (cont.)




on-shell W

off-shell W

# SUS-14-014

- Binning:
  - central: both leptons satisfy $|\eta| < 1.4$
  - forward: both leptons satisfy $1.6 < |\eta| < 2.4$
  - $\geq$ 2 jets and MET > 150 GeV
  - $\geq$ 3 jets and MET > 100 GeV
  - $m_{OSSF}$ (determined before looking at data):
    - below Z: 20–70 GeV
    - on Z: 81–101 GeV
    - above Z: > 120 GeV

# SUS-14-014

- Backgrounds:
  - Flavor-symmetric: OF as often as SF pairs (ttbar-dominated)
    - Determined in an opposite-flavor control sample with scale factor
    - Scale factor determined with two methods:
      - Factorization method, combining reconstructing and trigger efficiencies from independent samples
      - Control region method, measuring the scale factor directly in a ttbar-dominated region
  - DY + jets:
    - edge search:
      - kinematic fit
    - counting experiment:
      - jet-Z balance (recoil of hadronic system) and MET template methods

# SUS-14-004

- Selection:
  - Single photon:
    - $p_T$ threshold 70 GeV
    - Trigger requires $H_T$ > 400 GeV
  - Diphotons, alternatively:
    - $p_T$ thresholds 26, 18 GeV, with invariant mass > 70 GeV
    - $p_T$ thresholds 36, 22 GeV
- Razor variables:
  - Group jets and photons into megajets. Select the pair with smallest sum of squared in variant masses
  - $M_R \equiv \sqrt{\left(|\vec{p}^{j_1}| + |\vec{p}^{j_2}|\right)^2 - \left(p_z^{j_1} + p_z^{j_2}\right)^2}, \qquad R \equiv \frac{M_T^R}{M_R}$
  - Signal region: $M_R$ > 600 GeV, $R^2$ > 0.02