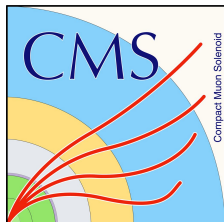


Search for SUSY with Photons at CMS

SUSY 17: 25th International Conference on SUSY and the Unification of
Fundamental Interactions, 11-15 Dec 2017, Mumbai (India)

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On behalf of CMS Collaboration

Indian Institute of Science Education & Research, Pune

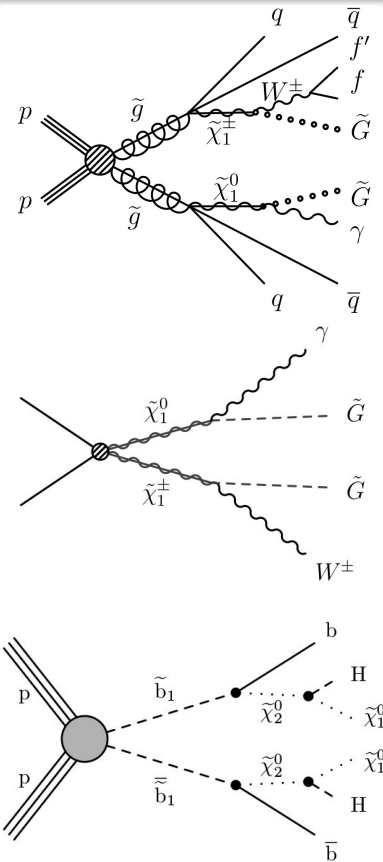


Introduction

- In gauge-mediated supersymmetry breaking (GMSB) scenario, NLSP (neutralino) can decay to a boson and a gravitino ($\tilde{G}$), LSP.
- For bino-like NLSP, $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$
- For bino and higgsino mixture,
 $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$
 or $\tilde{\chi}_1^0 \rightarrow Z + \tilde{G}$
 and/or $\tilde{\chi}_1^0 \rightarrow h(\rightarrow \gamma\gamma) + \tilde{G}$
- For wino-like (co-)NLSP, $\tilde{\chi}_1^0 \tilde{\chi}^\pm$ pair, with $\tilde{\chi}^\pm \rightarrow W^\pm + \tilde{G}$
- Decay of NLSP or decay of $h \rightarrow \gamma\gamma$ gives photonic signature.
- Some classic signatures with photons: di(photon) + p_T^{miss} and(or) lepton/jets/hadronic activity.

Search with Photons

- CMS experiment has performed a variety of SUSY searches with photon in the final state using pp collision data in Run 1 and Run 2. A complete information of all the results is available at [twiki](#).
- The results presented today are based on 36/fb of data collected at $\sqrt{s} = 13$ TeV.
 - SUS-16-047: $\gamma + \text{HT}\gamma + p_{\text{T}}^{\text{miss}}$
 - Targeting gluino pair production with large hadronic activity.
 - SUS-16-046: $\gamma + p_{\text{T}}^{\text{miss}}$
 - Targeting electroweak production of NLSP.
 - SUS-16-045 : $h \rightarrow \gamma\gamma$ using razor variables
 - Targeting anomalous higgs production.

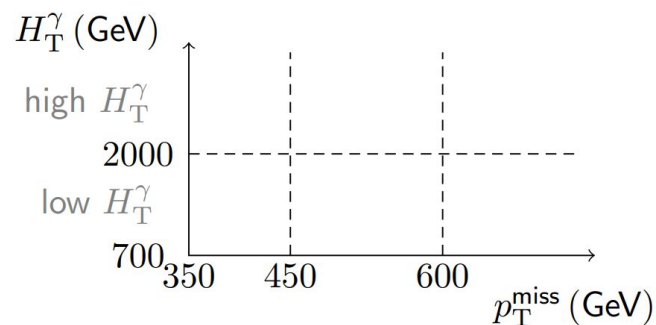
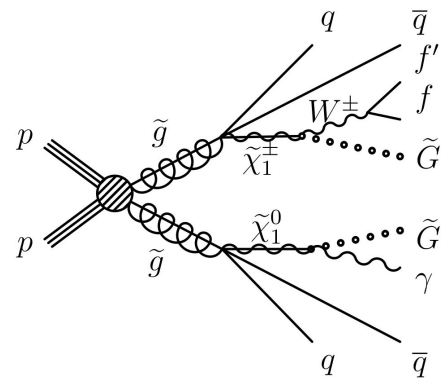


SUS-16-047: $\gamma + \text{HT}\gamma + p_{\text{T}}^{\text{miss}}$

Event Selection for $\gamma + \text{HT}\gamma + p_T^{\text{miss}}$

≥ 1 photon	$p_T > 100 \text{ GeV}, \eta < 1.44$
Hadronic (jet) activity $\text{HT}\gamma = \sum p_{T_{\text{jets}}} + p_{T_\gamma}$	$\text{HT}\gamma > 700 \text{ GeV}$ $p_{T_{\text{jets}}} > 30 \text{ GeV}, \eta < 3.0$
Presence of LSPs	$p_T^{\text{miss}} > 350 \text{ GeV}$
Reject events with mismeasured objects	$ \Delta\phi(\pm \mathbf{p}_T^{\text{miss}}, \mathbf{p}_{T_\gamma}) > 0.3.$

- Divide the search region phase space in bins of $\text{HT}\gamma$ & p_T^{miss} .

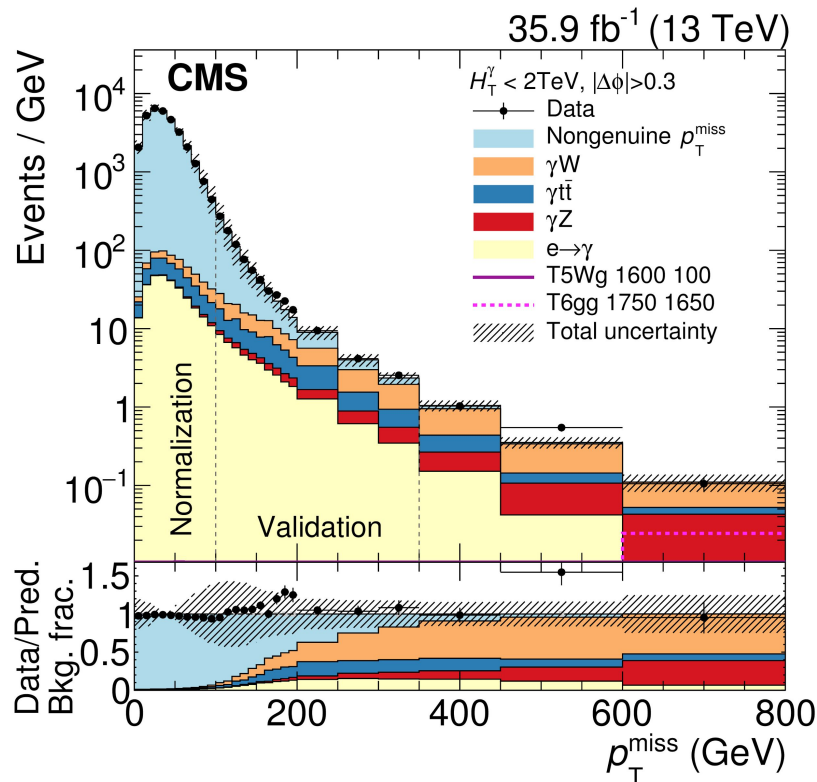


Backgrounds for $\gamma + \text{HT}\gamma + p_T^{\text{miss}}$

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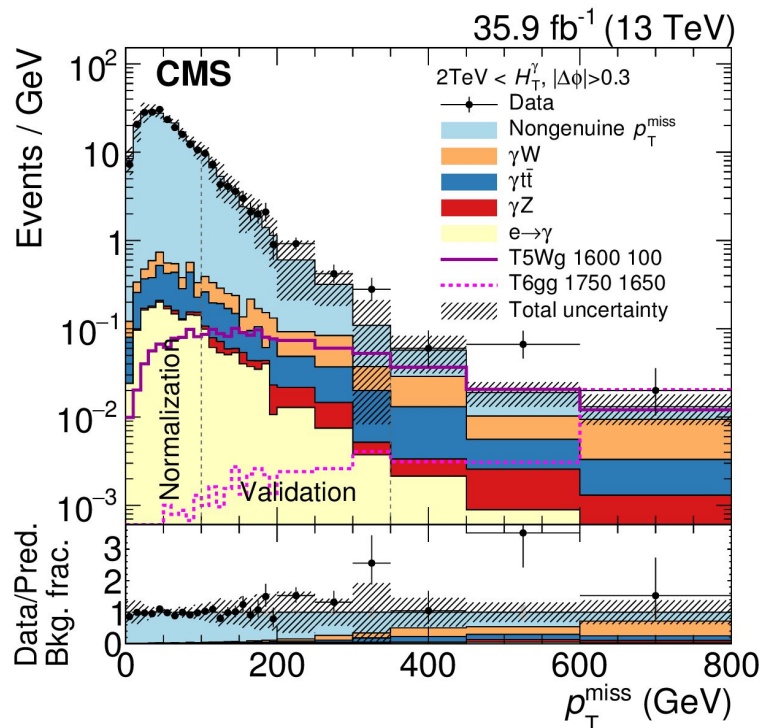
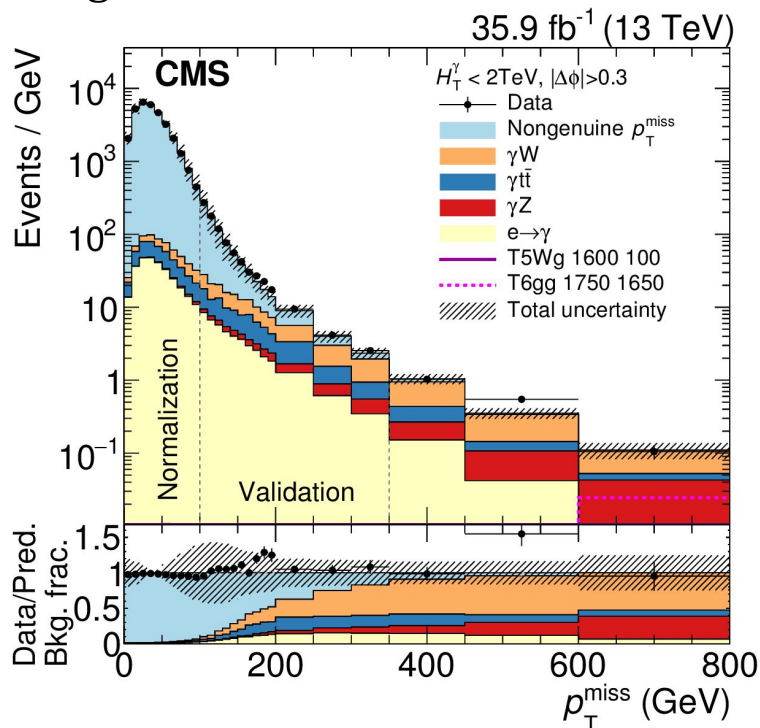
Background Estimations:

1. W/ttbar with $e+\nu$ decays and electron faking as γ ($e \rightarrow \gamma$)
 - a. Control sample with electron, scaled by electron mis-reconstruction probability.
2. QCD multijet+ γ +jets - Non-genuine p_T^{miss} :
 - a. Control sample without photon (jet dominated); corrected & normalized in low p_T^{miss} .
3. $W\gamma + Z\gamma + \text{tt}\gamma$: Decays involving neutrinos.
 - a. Taken from simulation.

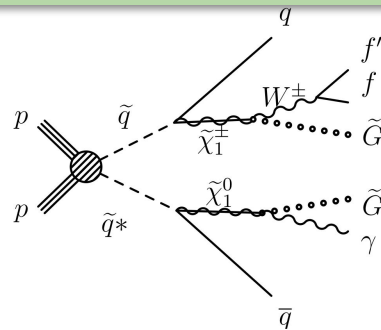
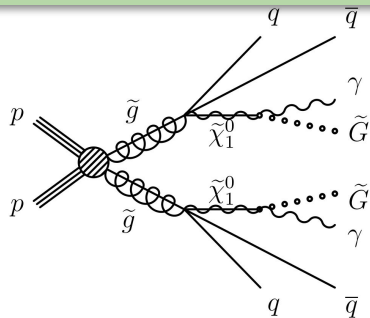


Results

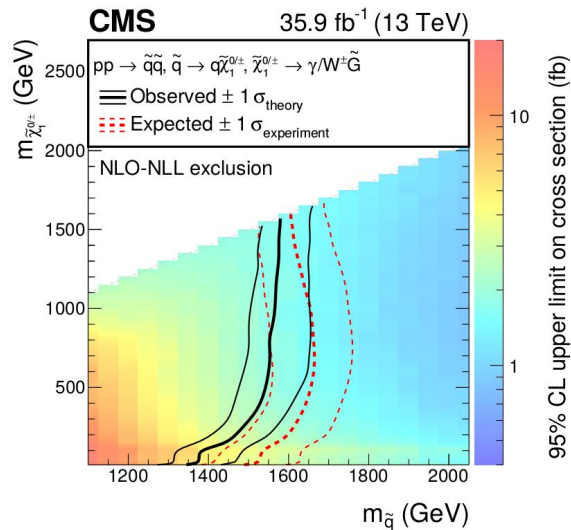
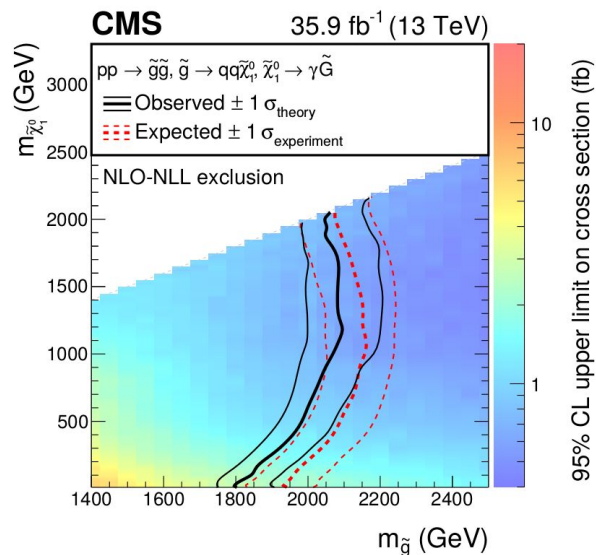
- 3 search bins in low HT_γ and 3 bins in high ($>2\text{TeV}$) HT_γ .
- No significant excess.



Interpretations



[arXiv:1707.06193](https://arxiv.org/abs/1707.06193)

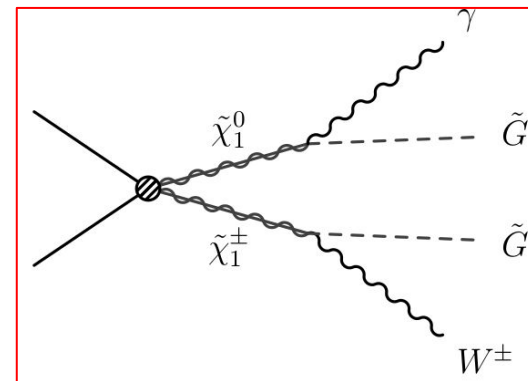


SUS-16-046: $\gamma + p_T^{\text{miss}}$

Event Selection for $\gamma + p_T^{\text{miss}}$

- Mainly targeted for EW production of NLSP.
- Complementary to $\gamma + \text{HT}\gamma + p_T^{\text{miss}}$.

$\geq 1\gamma$	$p_T > 180 \text{ GeV}, \eta < 1.44$
$\Delta R(\gamma, \text{nearest jet})$	> 0.5
$\Delta\phi(p_T^{\text{miss}}, \text{jet})$	$> 0.3, \text{ if jet } p_T > 100 \text{ GeV}$
$p_T^{\text{miss}} \text{ \& } M_T(\gamma, p_T^{\text{miss}})$	$> 300 \text{ GeV}, > 300\text{GeV}$

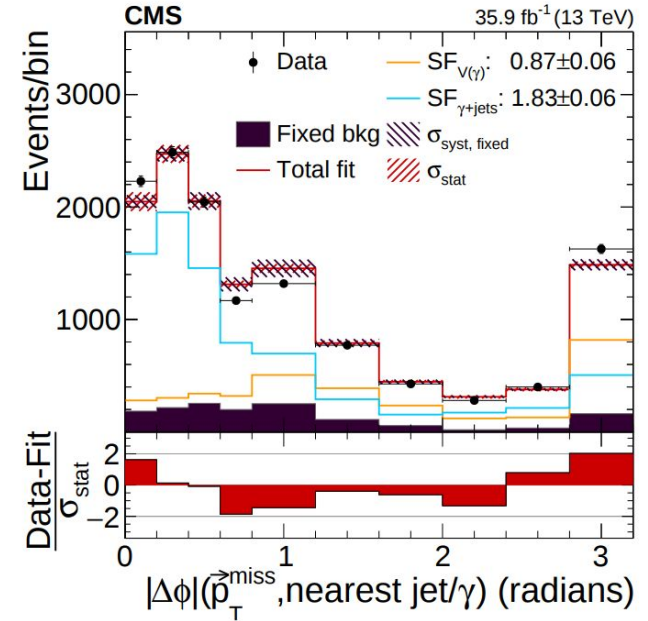
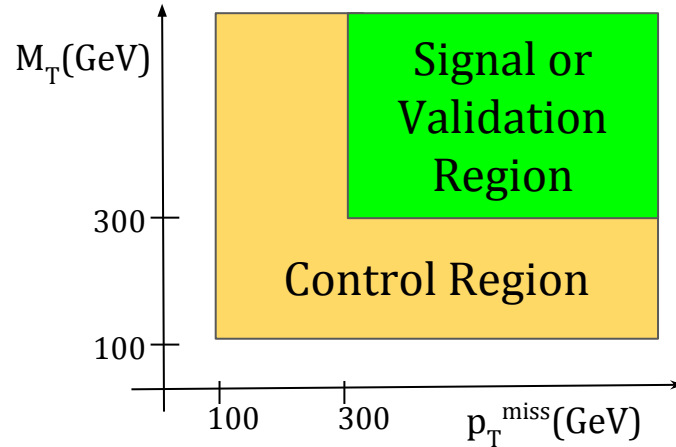


Backgrounds for $\gamma + p_T^{\text{miss}}$

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Background Estimations:

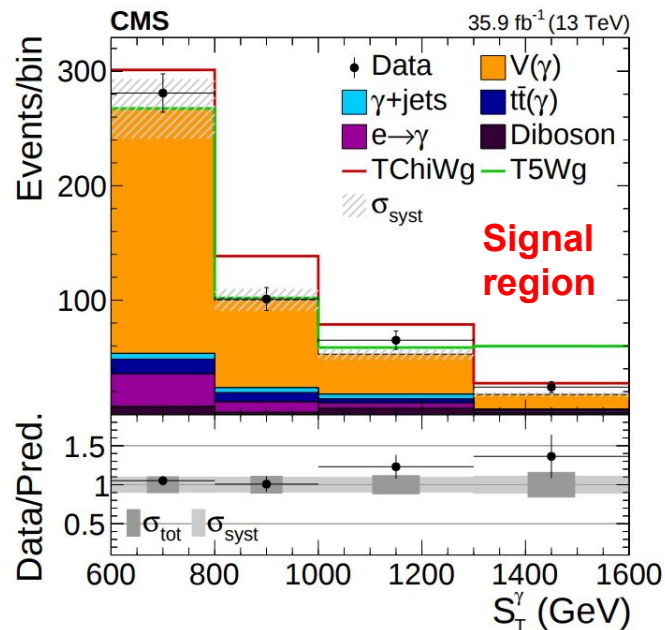
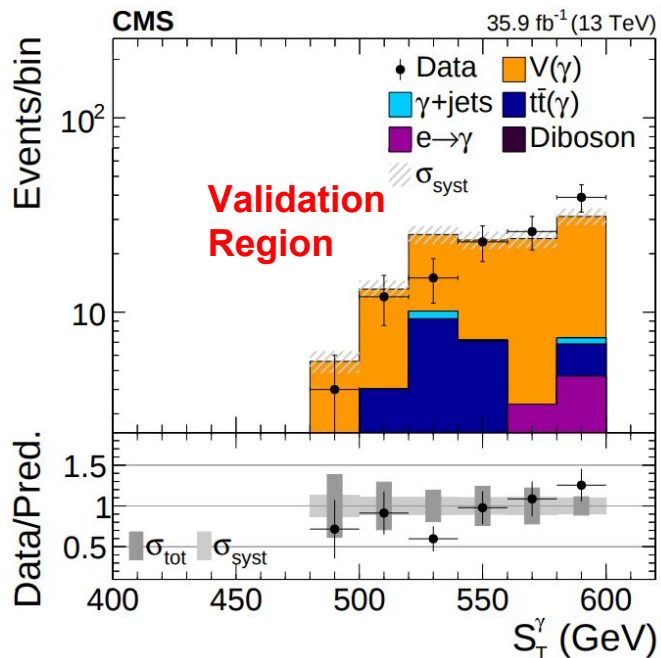
- $Z(\rightarrow \nu\nu)\gamma$, $W(\rightarrow l\nu)\gamma$ and $\gamma + \text{jets}$: Scaling simulation in a control region using template fit.
- $e \rightarrow \gamma$: Control sample with electron, scaled by electron mis-reconstruction probability.
- $t\bar{t}\gamma + \text{diboson}$: simulation.



Results

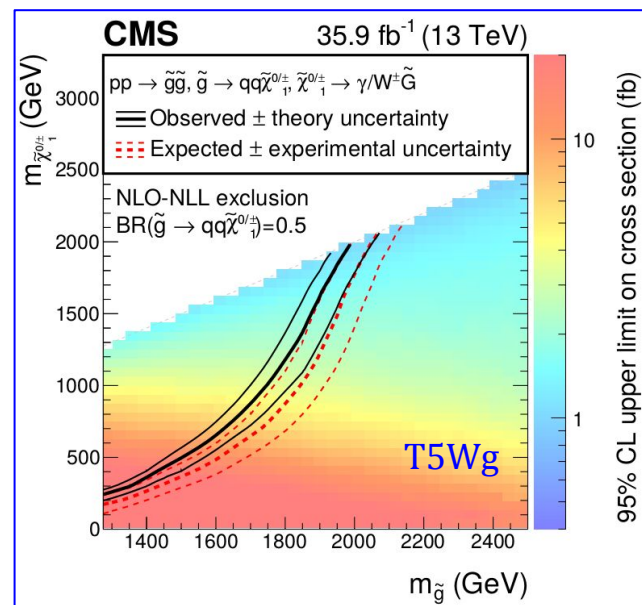
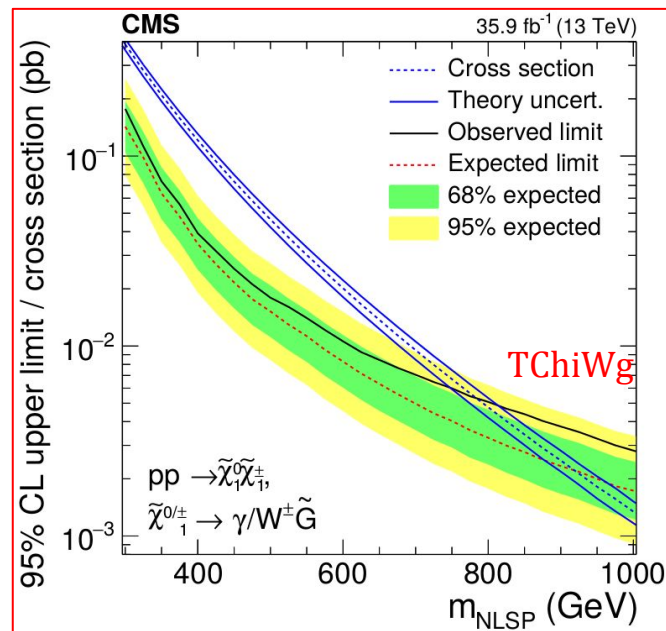
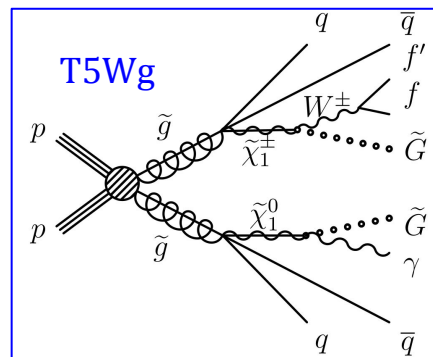
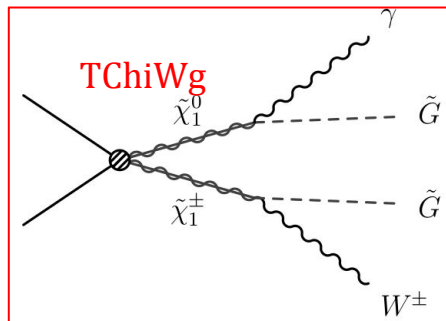
Validated in low S_T^γ region ($<600\text{GeV}$) & signal region is binned in high S_T^γ ($\geq 600\text{GeV}$).

$$S_T^\gamma \equiv p_T^{\text{miss}} + \sum_{\gamma_i} p_T(\gamma_i)$$



Interpretation

- NLSP masses below 750 GeV for TChiWg are excluded (95% CL).
- Gluinos below 1.95 TeV are excluded for T5Wg, for $m(\text{NLSP}) \sim m(\text{gluino})$.



[arXiv:1711.08008](https://arxiv.org/abs/1711.08008)

SUS-16-045 : $h \rightarrow \gamma\gamma$

Event Selection for $h \rightarrow \gamma\gamma$ using razor variables

- An inclusive search for anomalous Higgs boson production.

$$M_R \equiv \sqrt{(|\vec{p}^{j_1}| + |\vec{p}^{j_2}|)^2 - (p_z^{j_1} + p_z^{j_2})^2},$$

$$R^2 \equiv \left(\frac{M_T^R}{M_R} \right)^2, \quad \textbf{Razor variables}$$

$$M_T^R \equiv \sqrt{\frac{E_T^{\text{miss}}(p_T^{j_1} + p_T^{j_2}) - \vec{p}_T^{\text{miss}} \cdot (\vec{p}_T^{j_1} + \vec{p}_T^{j_2})}{2}}$$

j1 & j2 : 2 megajets, one clustered using h candidate & any other clustered using remaining jet(s).

- Typically SUSY signals have larger values for razor variables.

2γ	$p_T > 40(20) \text{ GeV}, \eta < 1.44$
$M(\gamma\gamma) \text{ in GeV}$	103 -160
$\geq 1 \text{ jet}$	$p_T > 30 \text{ GeV} \ \& \ \eta < 3.0$
M_R	$> 150 \text{ GeV}$

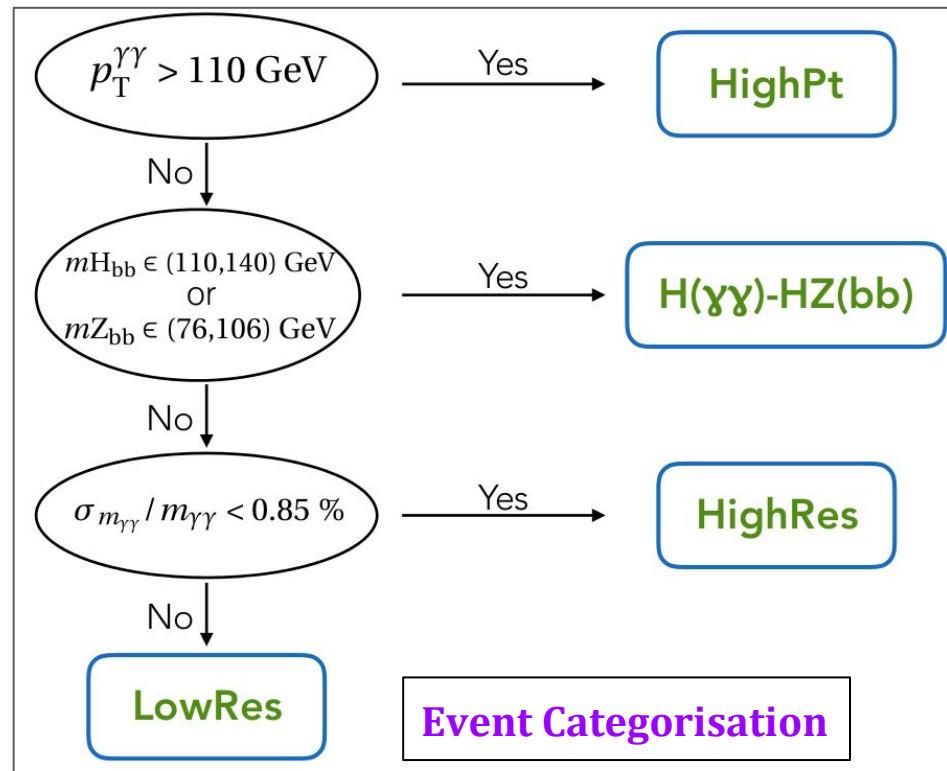
Backgrounds for $h \rightarrow \gamma\gamma$ and Event Categorisation

Backgrounds:

- SM higgs production: estimated from simulation.
- Non-resonant background is estimated by using a fit to di-photon invariant mass distribution in data.

Search Regions:

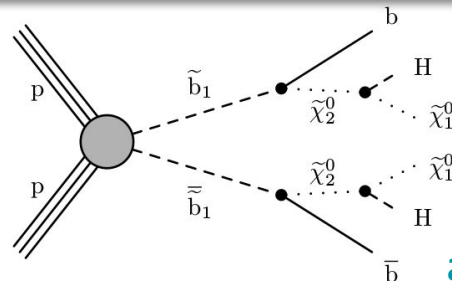
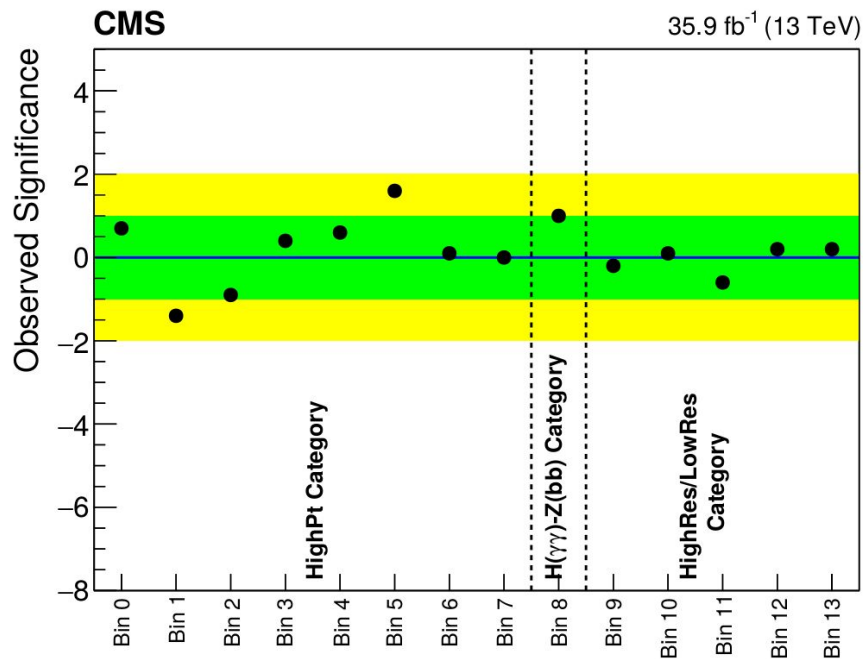
- Each of the event categories is further divided in bins of razor variables (M_R & R^2).



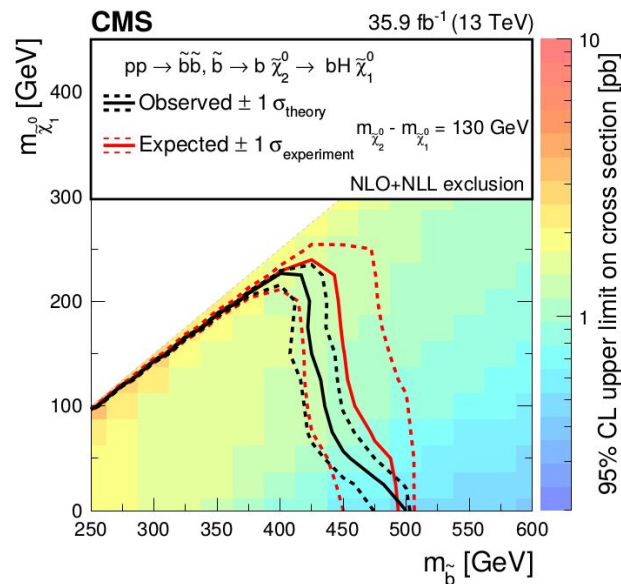
Results & Interpretations

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Observed significance in each search bin:



[arXiv:1709.00384](https://arxiv.org/abs/1709.00384)



Summary

- Searches for SUSY with photon(s) in the final state and anomalous higgs production have been presented using 36fb^{-1} of data collected by CMS.
- None of the searches show significant deviation from SM processes.
- Stay tuned for results from 2016 & 2017 data!

References

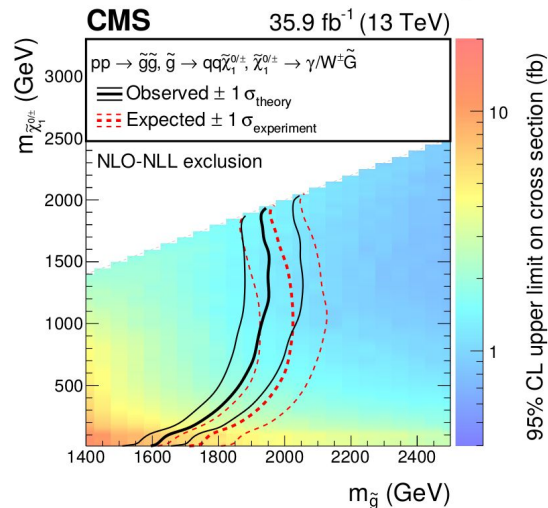
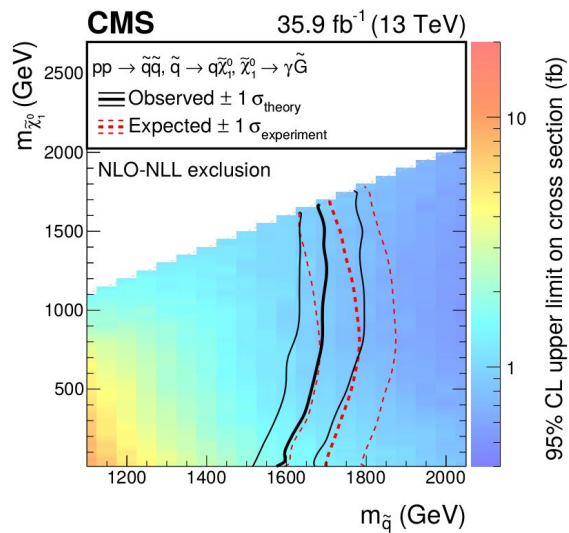
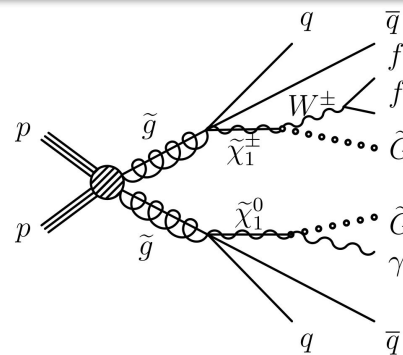
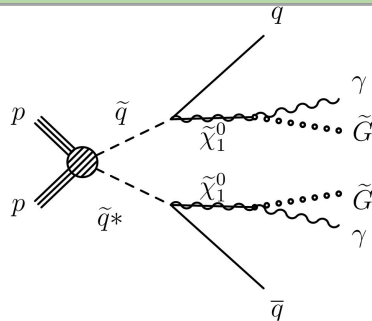
Search	Publication/arXiv	CMS Public Results	Submitted To
$\gamma + \text{HT}\gamma + p_{\text{T}}^{\text{miss}}$	arXiv:1707.06193	SUS-16-047	JHEP
$\gamma + p_{\text{T}}^{\text{miss}}$	arXiv:1711.08008	SUS-16-046	Phys. Lett. B
Razor $h \rightarrow \gamma\gamma$	arXiv:1709.00384	SUS-16-045	Phys. Lett. B

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

Backup Slides

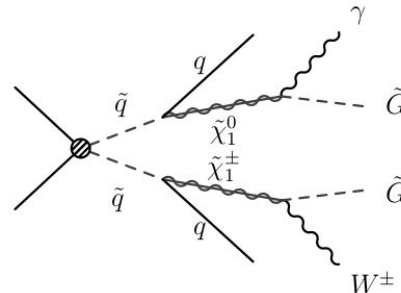
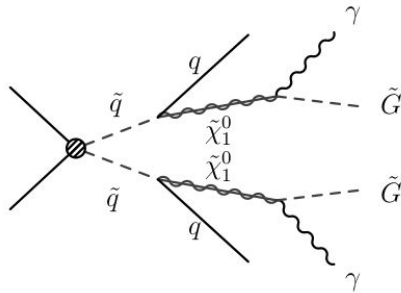
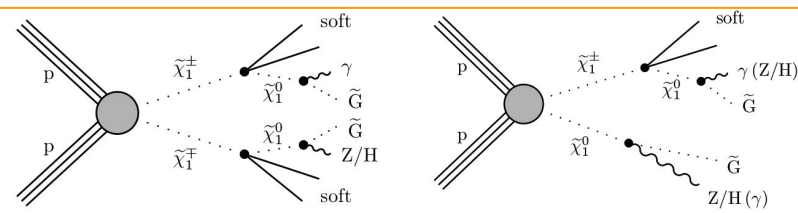
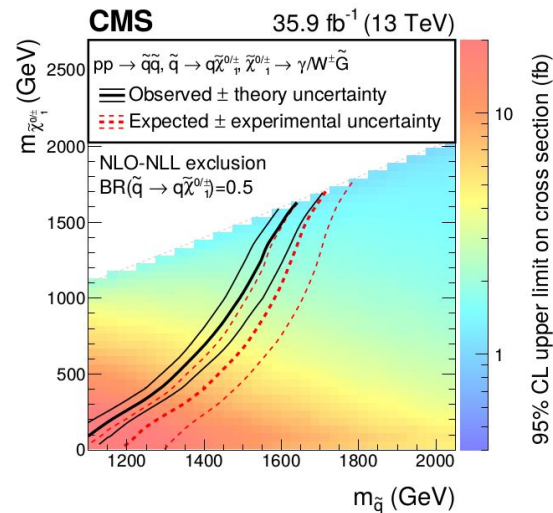
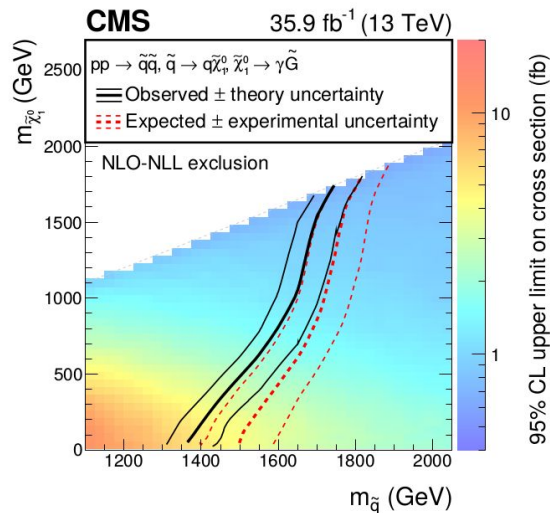
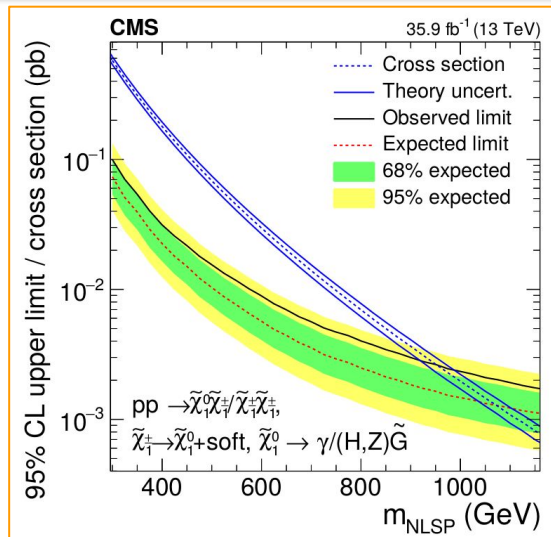
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Interpretations for $\gamma + \text{HT} \gamma + p_T^{\text{miss}}$

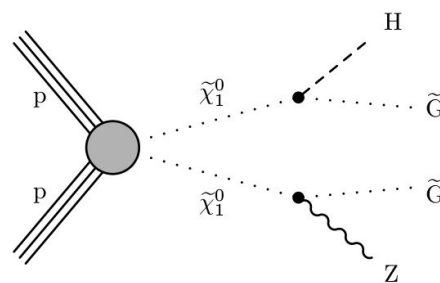
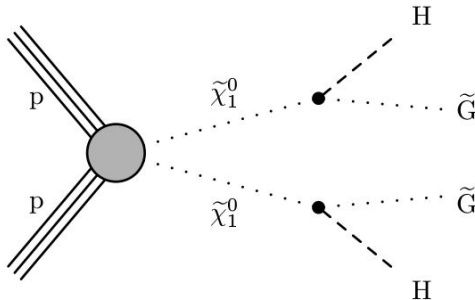
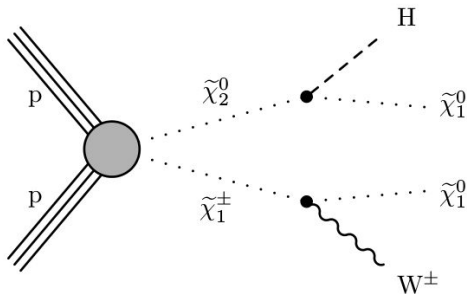
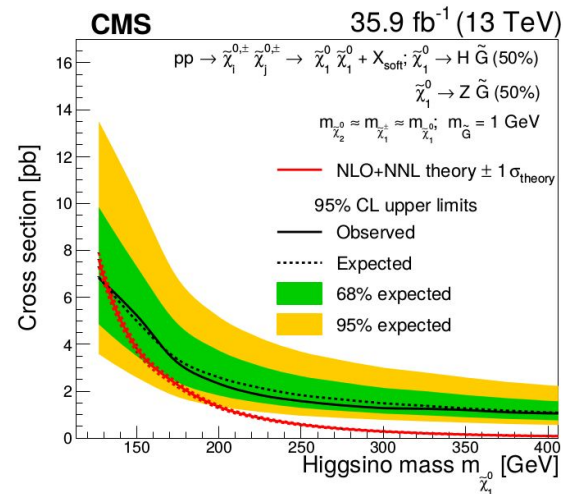
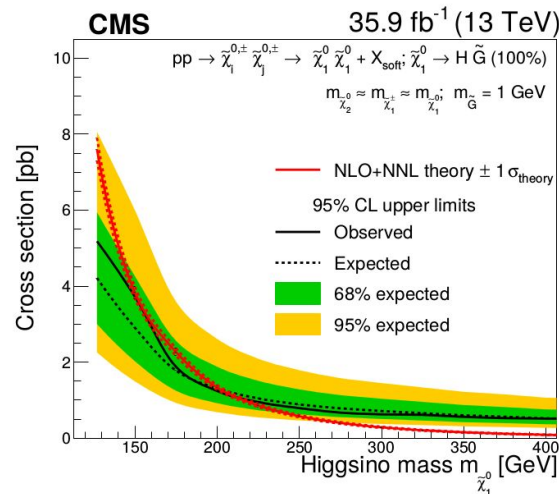
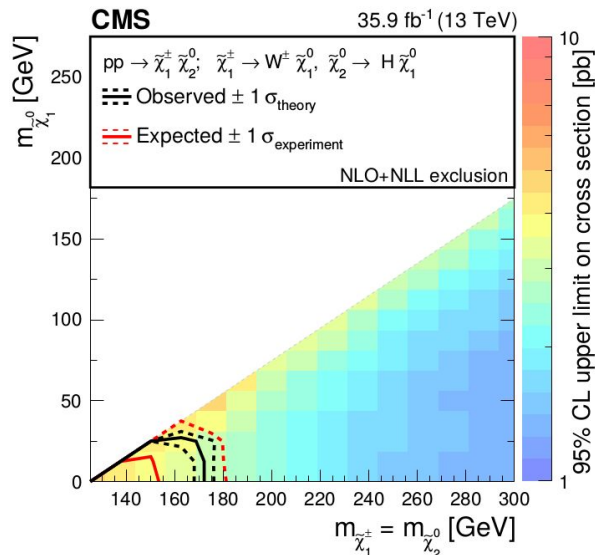


Interpretations for $\gamma + p_T^{\text{miss}}$

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Interpretations for $h \rightarrow \gamma\gamma$ Using Razor Variables



Search Bins for $h \rightarrow \gamma\gamma$ Using Razor Variables

Bin number	Category	M_R (GeV)	R^2
0	HighPt	≥ 600	≥ 0.025
1	HighPt	150–600	≥ 0.130
2	HighPt	≥ 1250	0.000–0.025
3	HighPt	150–450	0.000–0.130
4	HighPt	450–600	0.000–0.035
5	HighPt	450–600	0.035–0.130
6	HighPt	600–1250	0.000–0.015
7	HighPt	600–1250	0.015–0.025
8	H($\gamma\gamma$)-HZ(bb)	≥ 150	≥ 0.0
9	HighRes	150–250	0.000–0.175
	LowRes	150–250	0.000–0.175
10	HighRes	150–250	≥ 0.175
	LowRes	150–250	≥ 0.175
11	HighRes	≥ 250	≥ 0.05
	LowRes	≥ 250	≥ 0.05
12	HighRes	250–600	0.000–0.05
	LowRes	250–600	0.000–0.05
13	HighRes	≥ 600	0.000–0.05
	LowRes	≥ 600	0.000–0.05