Search for SUSY in multilepton final states at CMS

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on behalf of CMS Collaboration

CMS lepton SUSY searches

CMS searches for SUSY in wide range of final states, including final states with leptons

no leptons	1 lepton	2 leptons	**≥ 3 leptons**
Covered by Josh's talk	Covered by Marco Andrea's talk		Covered by this talk

Events with multiple leptons provide a clean and well controlled environment for evidence of new physics Beyond the Standard Model.

CMS searches are SUSY model-independent, but in this talk several interpretions of results in chosen specific SUSY models are shown.

In the following, results from two analysis will be shown.
Both of them used the full dataset 2012 LHC proton proton collisions at center-of-mass energy of 8 TeV, corresponding to $L \approx 20\ fb^{-1}$.

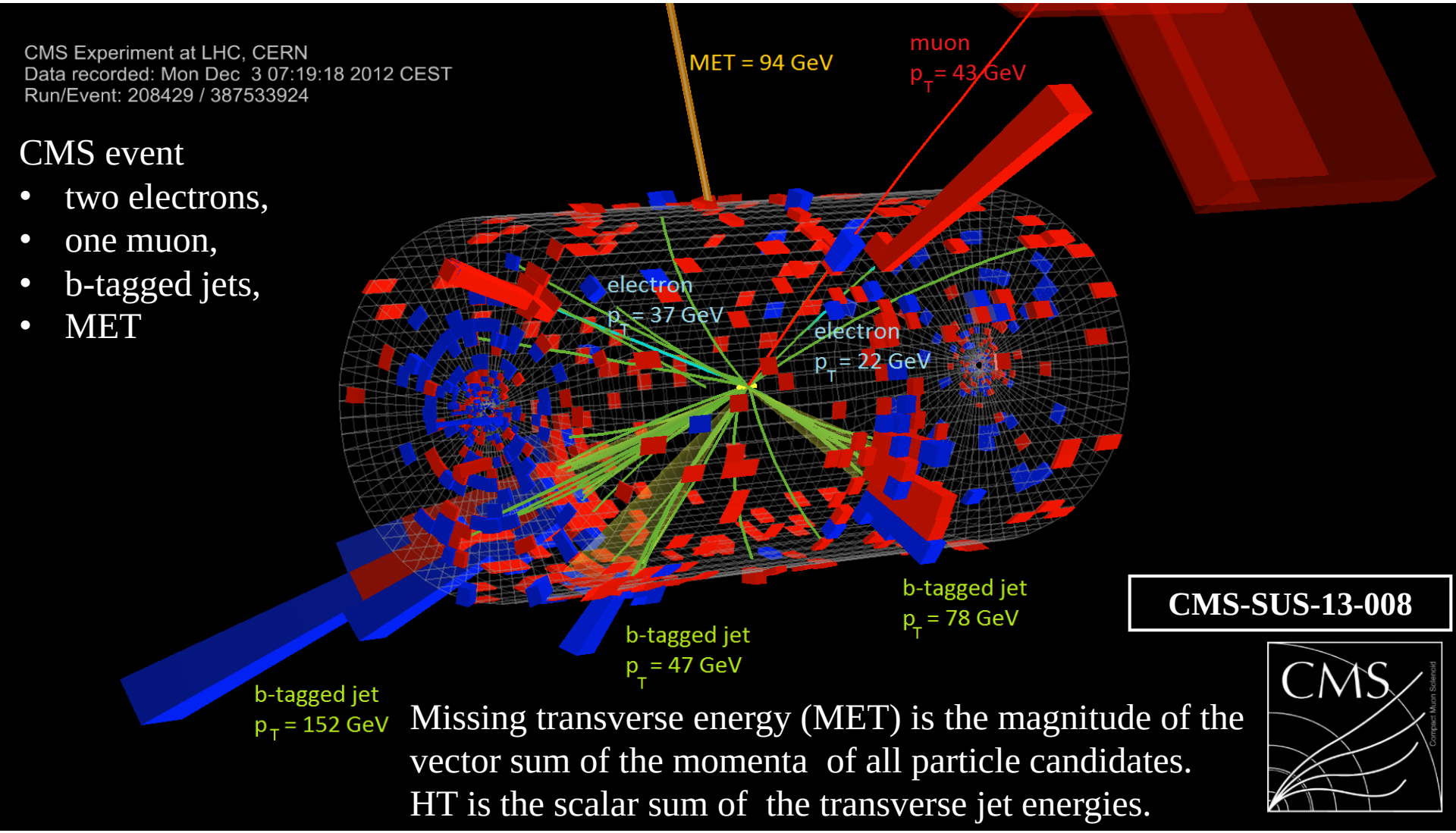
≥3 leptons inclusive searches

CMS-SUS-13-002

=3 leptons + ≥ 1 b jets inclusive targeted searches

CMS-SUS-13-008

CMS



CMS event

- two electrons,
- one muon,
- b-tagged jets,
- MET

CMS-SUS-13-008

Missing transverse energy (MET) is the magnitude of the vector sum of the momenta of all particle candidates. HT is the scalar sum of the transverse jet energies.

Physics objects

CMS-SUS-13-002
CMS-SUS-13-008

Online selections with dilepton (DoubleMu, DoubleEle, MuE) triggers
first lepton p_T > 17 GeV, second lepton p_T > 8 GeV

Event selections
first lepton p_T > 20 GeV, other leptons p_T > 10 GeV

CLASSIFICATION

Optimized signal regions to achieve greater sensitivity
to an array of different SUSY cascades
Many mutually exclusive with varying requirements on

- Number of leptons
- Lepton and jet flavor, charge and flavor combinations
- Number of jets
- Number of b-jets
- MET
- HT

A search for anomalous production of events with three or more leptons

CMS-SUS-13-002

Searching strategies

CMS-SUS-13-002

Candidate multilepton events

- ≥ 3 lepton candidates

MET distributions for 64 categories

Example of results table with categories

3 leptons, maximum number of opposite-sign same flavor (OSSF) dilepton pair , presence of τ, presence of a leptonically-decaying Z if at least one OSSF pair invariant mass is in Z mass window, presence of b tagged jets, HT, MET

Selection 3 Lepton Results			E_T^{miss}	$N(\tau_h)=0$, $N_{b-jets}=0$		$N(\tau_h)=1$, $N_{b-jets}=0$		$N(\tau_h)=0$, $N_{b-jets}\geq 1$		$N(\tau_h)=1$, $N_{b-jets}\geq 1$	
				obs	exp	obs	exp	obs	exp	obs	exp
OSSF0	$H_T > 200$	NA	(100,∞)	5	3.7 ± 1.6	35	33 ± 14	1	5.5 ± 2.2	47	61 ± 30
OSSF0	$H_T > 200$	NA	(50,100)	3	3.5 ± 1.4	34	36 ± 16	8	7.7 ± 2.7	82	91 ± 46
OSSF0	$H_T > 200$	NA	(0,50)	4	2.1 ± 0.8	25	25 ± 9.7	1	3.6 ± 1.5	52	59 ± 29
OSSF1	$H_T > 200$	above-Z	(100,∞)	5	3.6 ± 1.2	2	10 ± 4.8	3	4.7 ± 1.6	19	22 ± 11
OSSF1	$H_T > 200$	below-Z	(100,∞)	7	9.7 ± 3.3	18	14 ± 6.4	8	9.1 ± 3.4	21	23 ± 11
OSSF1	$H_T > 200$	on-Z	(100,∞)	39	61 ± 23	17	15 ± 4.9	9	14 ± 4.4	10	12 ± 5.8
OSSF1	$H_T > 200$	above-Z	(50,100)	4	5 ± 1.6	14	11 ± 5.2	6	6.8 ± 2.4	32	30 ± 15
OSSF1	$H_T > 200$	below-Z	(50,100)	10	11 ± 3.8	24	19 ± 6.4	10	9.9 ± 3.7	25	32 ± 16
OSSF1	$H_T > 200$	on-Z	(50,100)	78	80 ± 32	70	50 ± 11	22	22 ± 6.3	36	24 ± 9.8
OSSF1	$H_T > 200$	above-Z	(0,50)	3	7.3 ± 2	41	33 ± 8.7	4	5.3 ± 1.5	15	23 ± 11
OSSF1	$H_T > 200$	below-Z	(0,50)	26	25 ± 6.8	110	86 ± 23	5	10 ± 2.5	24	26 ± 11
OSSF1	$H_T > 200$	on-Z	(0,50)	*135	127 ± 41	542	543 ± 159	31	32 ± 6.5	86	75 ± 19

Background estimations

CMS-SUS-13-002

- Background from non-prompt leptons or tau candidates

Z boson production with associated jets, where Z decays leptonically and a third lepton is a result of misidentification from a jet

→ Data driven method to estimate contributions from Drell -Yan

- Irreducible background from WZ production

Diboson + jets production where both bosons decay leptonically

→ Expected rate from theory and Monte Carlo simulations

- Background from tt(bar) production

→ Estimation from simulation after validation procedures

- Backgrounds from asymmetric internal photon conversion

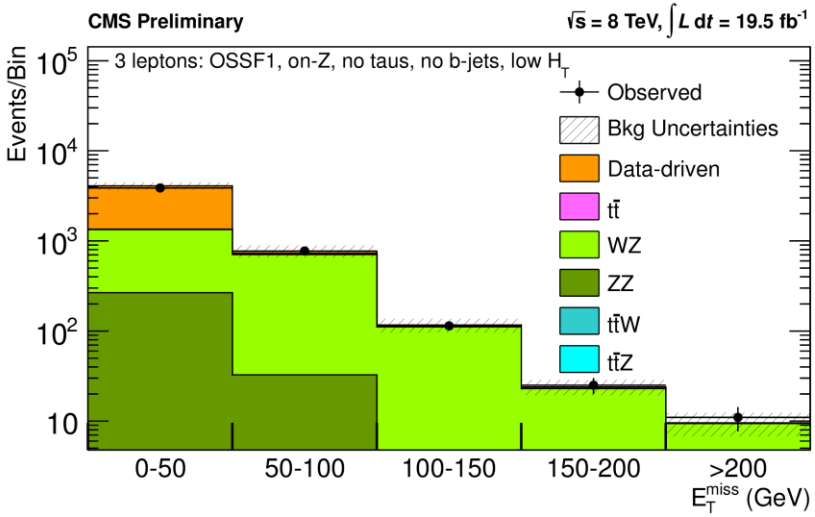
External conversion: an on-shell photon decays into a lepton pair in the material of the detector

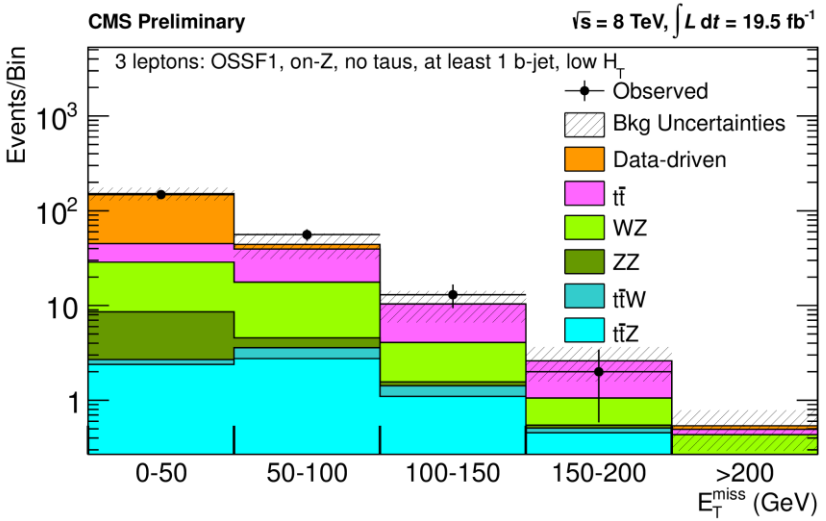
Internal conversion: virtual photon produces lepton pair

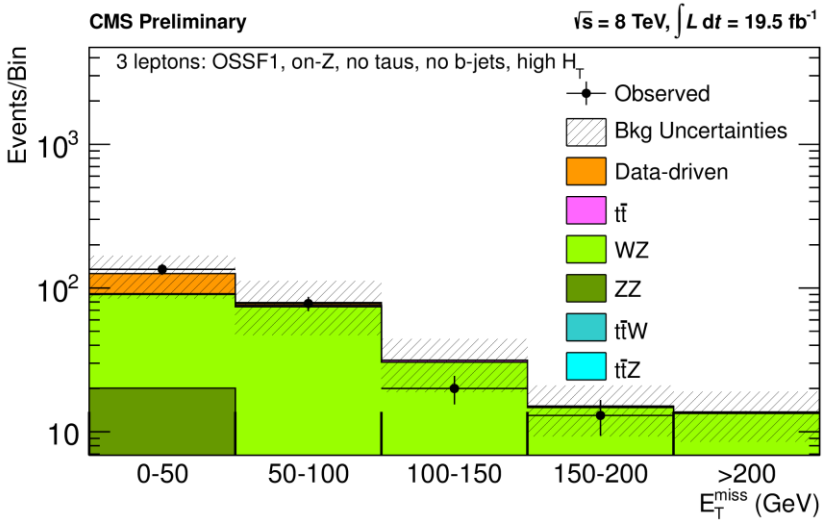
→ Estimation from data-based measurement

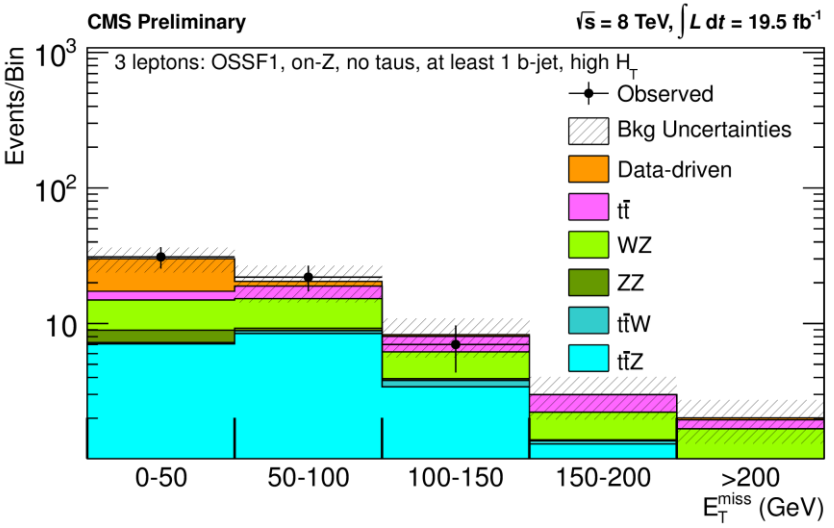
Search regions distributions

CMS-SUS-13-002



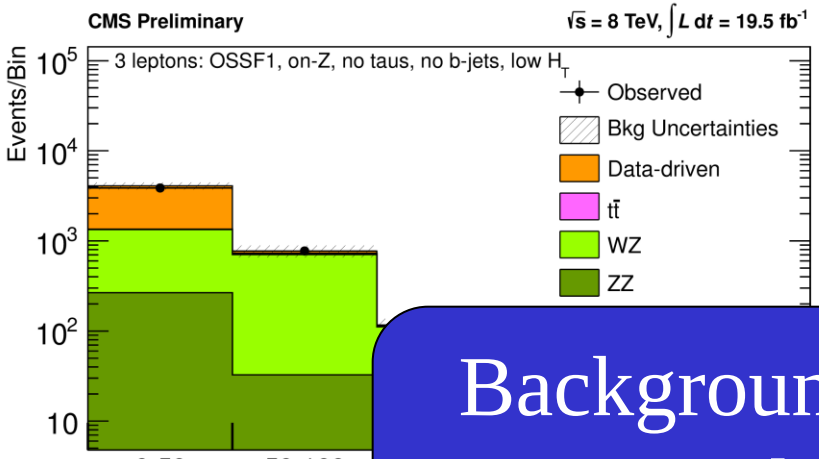


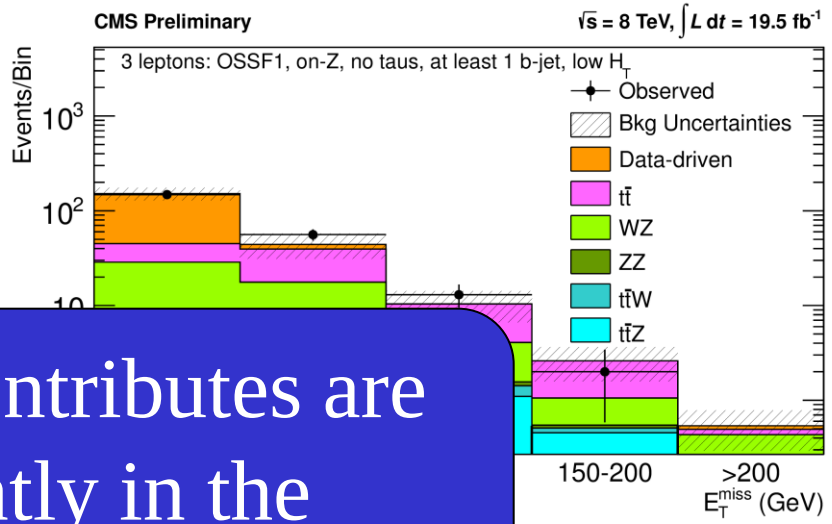




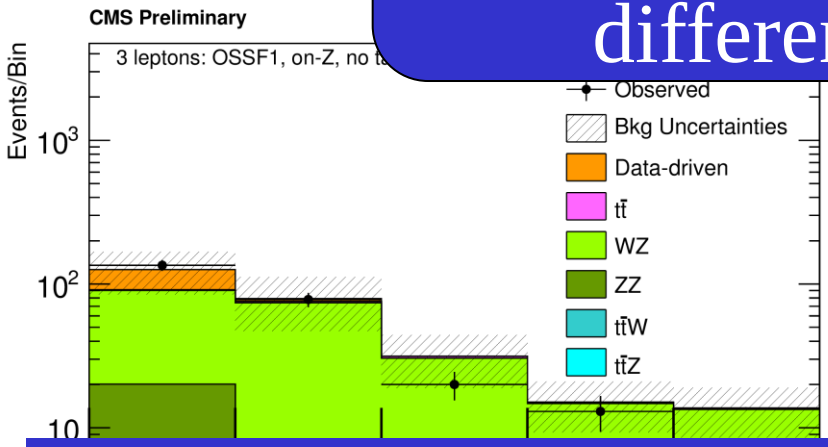
Search regions distributions

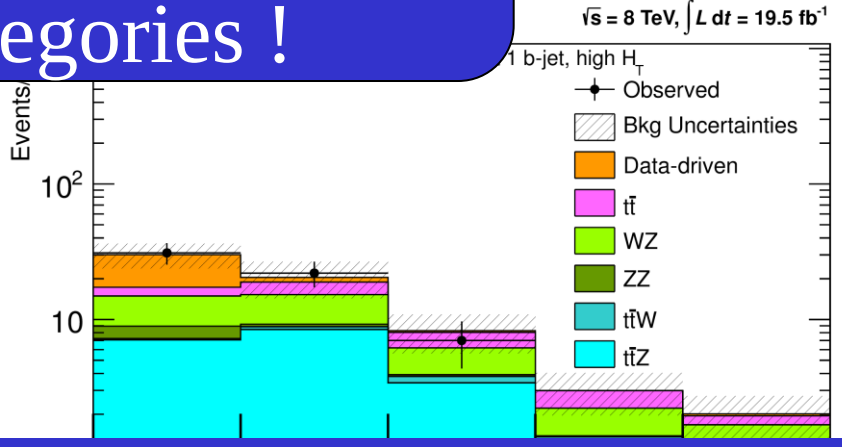
CMS-SUS-13-002





Backgrounds contributes are very differently in the different categories !



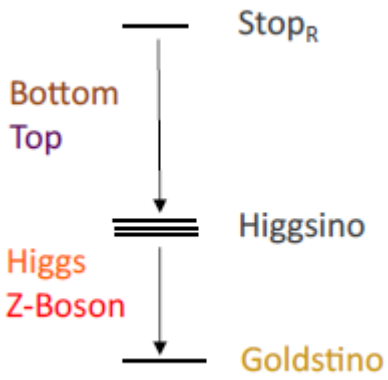


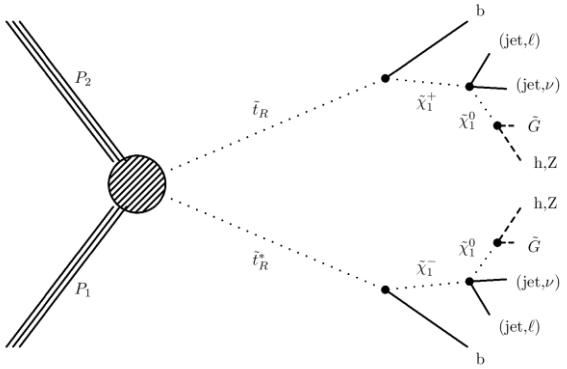
Fair agreement between SM predicted backgrounds and data

Natural Higgsino NLSP scenario

Gauge Mediated Supersymmetry Breaking (GMSB) model

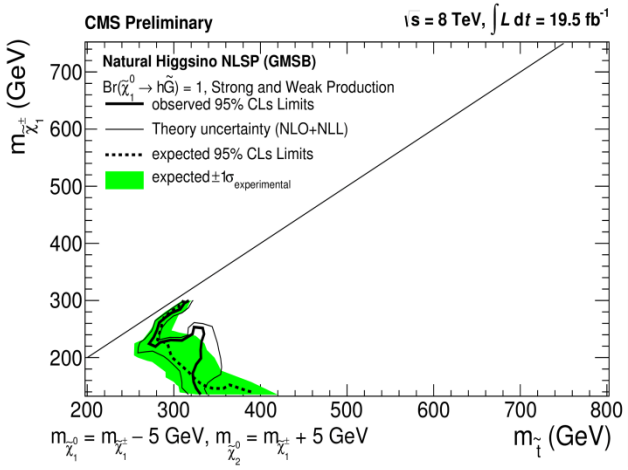
CMS-SUS-13-002

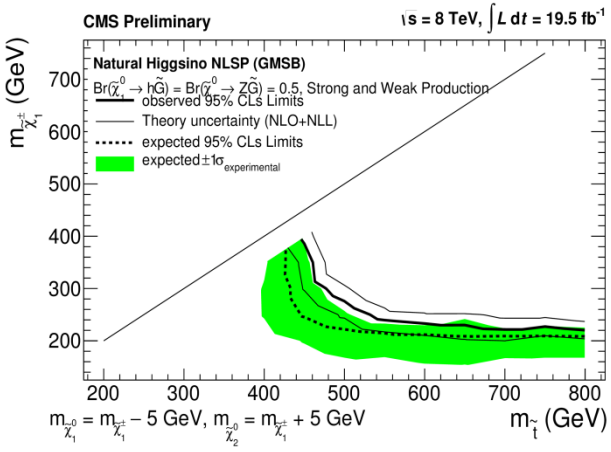


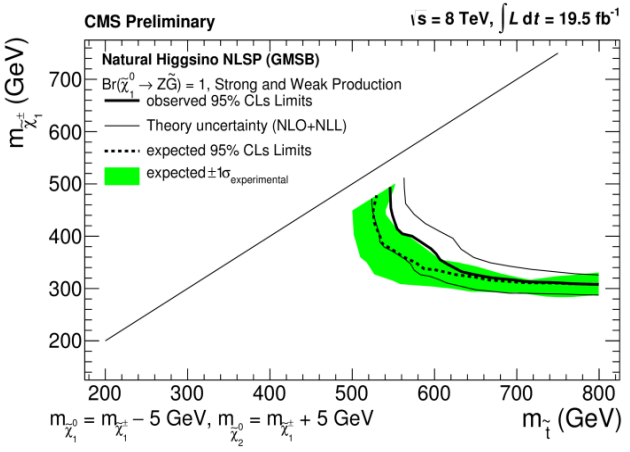


Top squark production with decays to neutral di-boson pair

Exclusion limits in the stop-chargino mass plane (different Br scenarios)

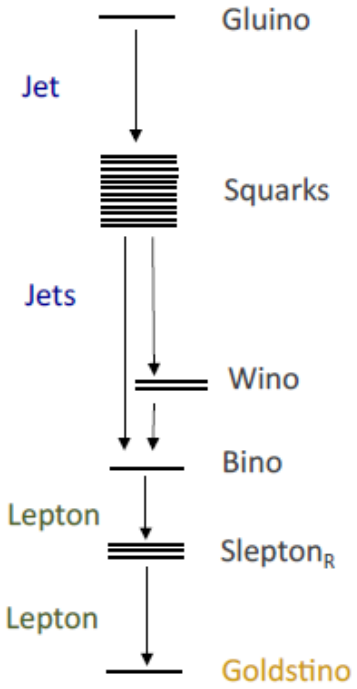


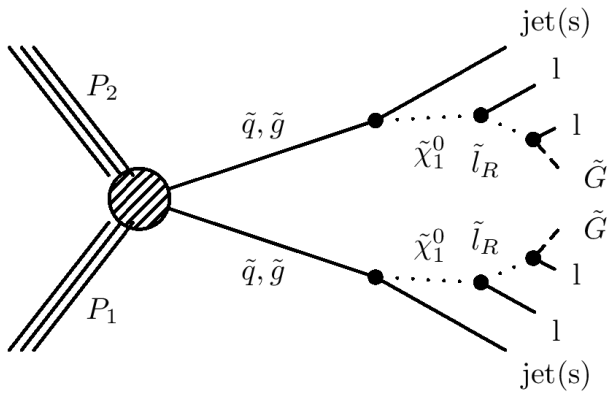




Slepton co-NLSP scenario

Gauge Mediated Supersymmetry Breaking (GMSB) model



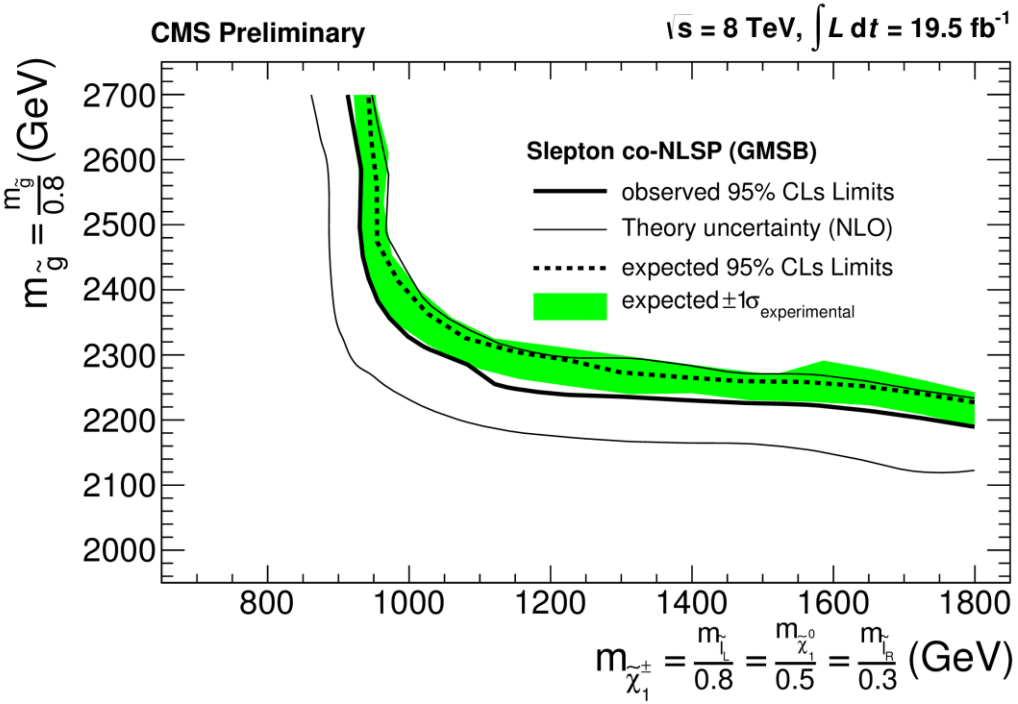


CMS-SUS-13-002

Model includes strong & weak production of squarks, gluinos, sleptons, gauginos

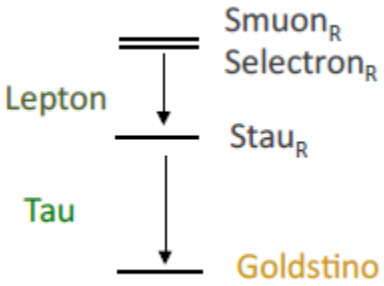
Signal populates high MET and 3 and 4 leptons channels.

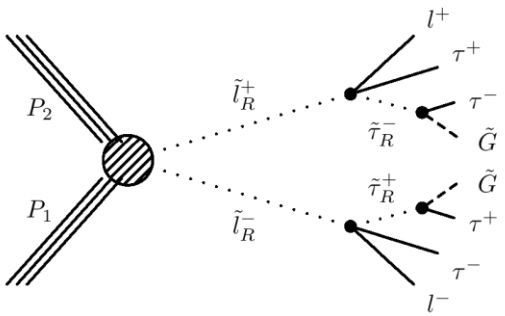
Exclusion limits in the lightest chargino-gluino mass plane



Stau (N)NLSP scenario

Gauge Mediated Supersymmetry Breaking (GMSB) model



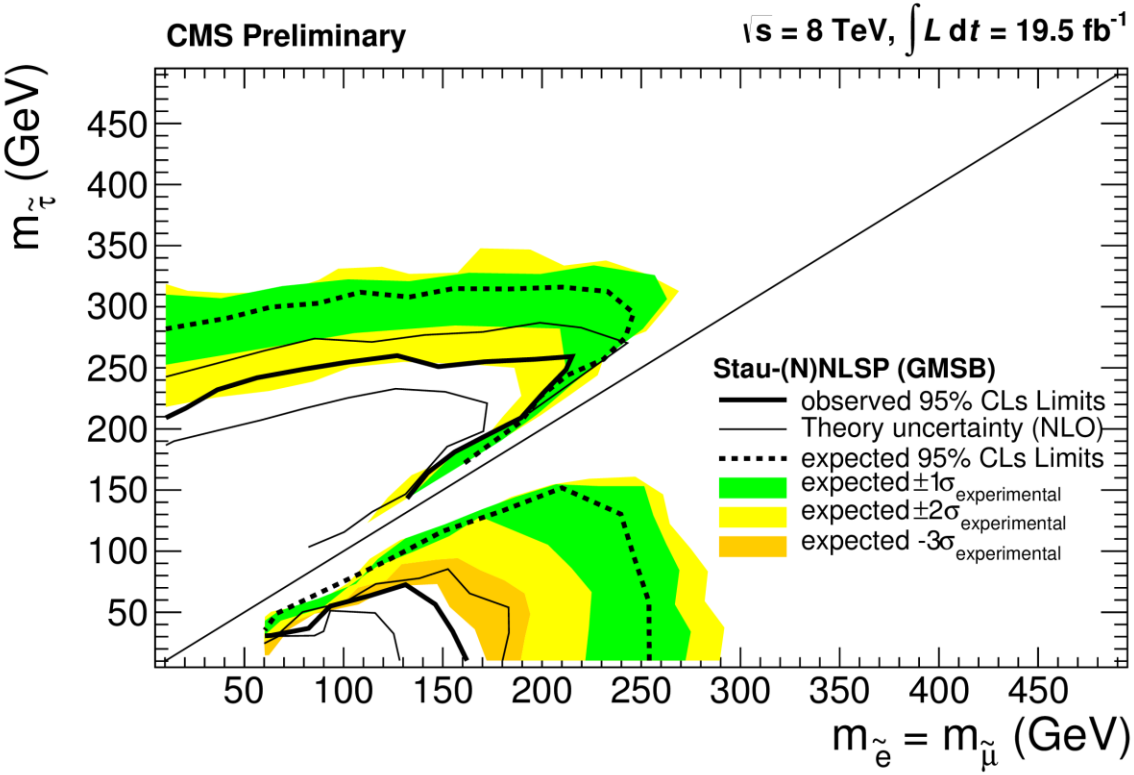


CMS-SUS-13-002

Electroweak production of right-handed sleptons

Signal populates high MET and τ channels.

Exclusion limits in the degenerate smuon- and selector-stau mass plane



Next slide
more on discrepancy

Origin & significance of discrepancy

CMS-SUS-13-002

Categorie:

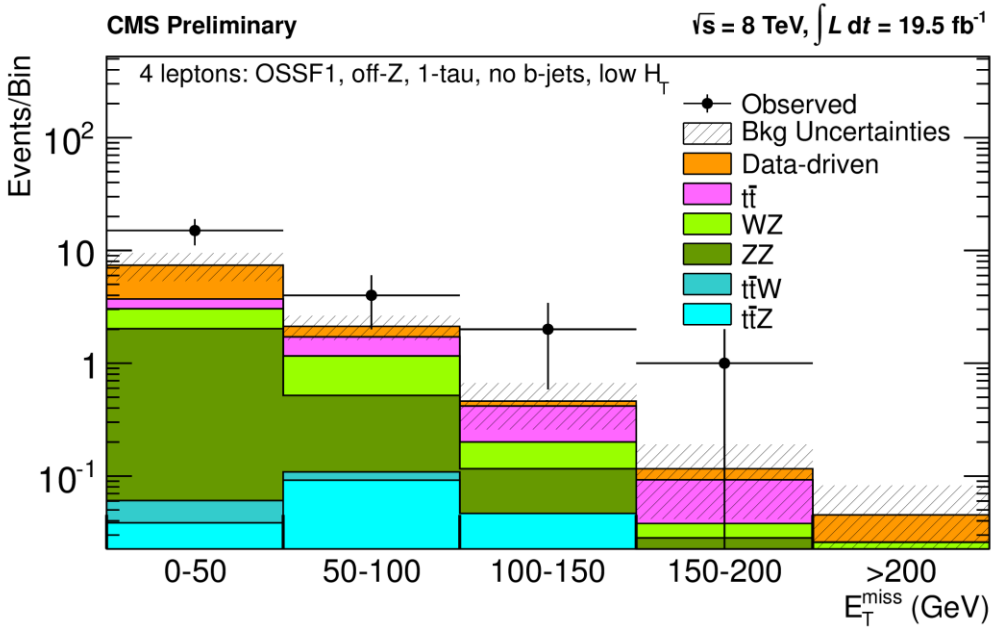
4 leptons, OSSF1, off-Z,

including 1 τ,

no b-tags, HT< 200 GeV

Observe = 22 events

Expected = 10 ± 2.4 events



Probability for 1 out of 64 categories to have as large a fluctuation ≈ 50 %

Probability for all bins in 1 out of 64 categories to have as large a fluctuation ≈ 5 %

Given that we search for new physics in 64 different categories of multi-lepton events, it is not surprising that we find one category with a large deviation between observed yield and expected SM background.

Search for supersymmetry in pp collisions at 8 TeV in events with three leptons and at least one b-tagged jet

CMS-SUS-13-008

Searching strategies

CMS-SUS-13-008

Candidate multilepton events

- = 3 lepton candidates + ≥ 2 jets + ≥ 1 b-tagged jet

Baseline selections

60 search regions

Variable	Baseline	Search Regions		
Sign/Flavor	3 e/μ	On-Z	Off-Z	
$N_{\text{b-jets}}$	≥ 1	1	2	≥ 3
N_{jets}	≥ 2	2–3	≥ 4	
H_T (GeV)	≥ 60	60–200	≥ 200	
E_T^{miss} (GeV)	≥ 50	50–100	100–200	≥ 200

Backgrounds

One or more non-prompt or misidentified leptons

Three prompt leptons from diboson production

Rare SM processes

Results in On Z regions

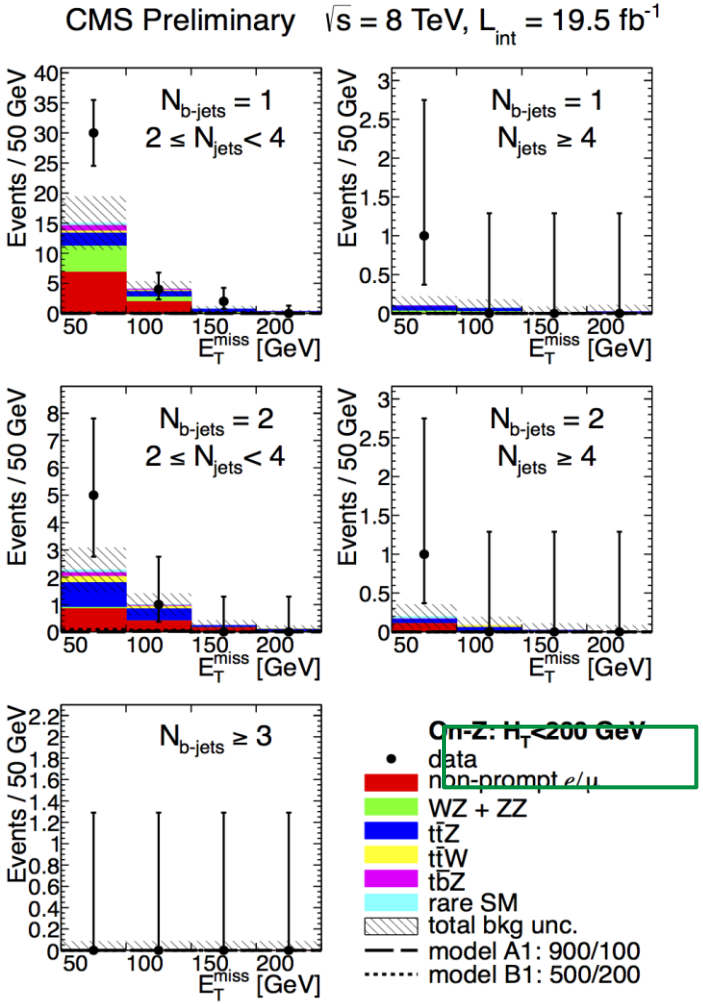
CMS-SUS-13-008

Searching results in different signal regions for events with a Z candidate present (On-Z)

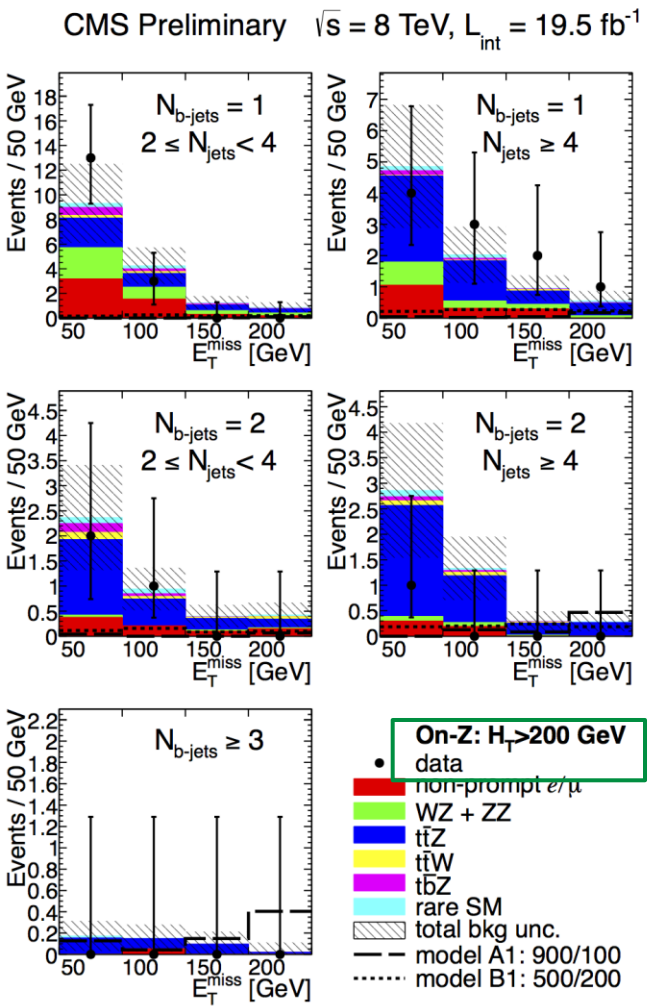
$N_{b\text{-tags}}$	N_{jets}	E_T^{miss} (GeV)	$H_T < 200$ GeV		$H_T > 200$ GeV	
			Expected	Observed	Expected	Observed
1	2–3	50–100	15.0 ± 4.5	30	9.3 ± 3.2	13
		100–200	5.0 ± 1.7	6	5.5 ± 2.0	3
		≥200	0.36 ± 0.22	0	0.9 ± 0.4	0
	≥4	50–100	0.11 ± 0.12	1	4.9 ± 2.0	4
		100–200	< 0.19	0	3.0 ± 1.3	5
		≥200	< 0.11	0	0.56 ± 0.31	1
2	2–3	50–100	2.3 ± 0.8	5	2.6 ± 1.0	2
		100–200	1.3 ± 0.5	1	1.3 ± 0.6	1
		≥200	0.12 ± 0.12	0	0.46 ± 0.24	0
	≥4	50–100	0.20 ± 0.16	1	2.9 ± 1.3	1
		100–200	< 0.22	0	1.6 ± 0.8	0
		≥200	< 0.09	0	0.29 ± 0.19	0
≥3		50–100	< 0.09	0	0.17 ± 0.14	0
		100–200	< 0.09	0	0.25 ± 0.16	0
		≥200	< 0.09	0	0.02 ± 0.09	0

Search regions distributions

CMS-SUS-13-008



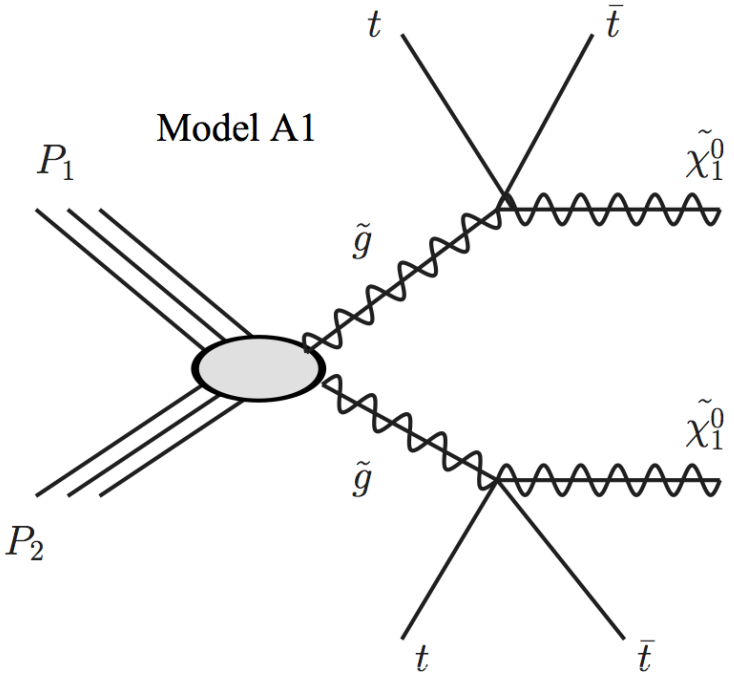
On Z categories



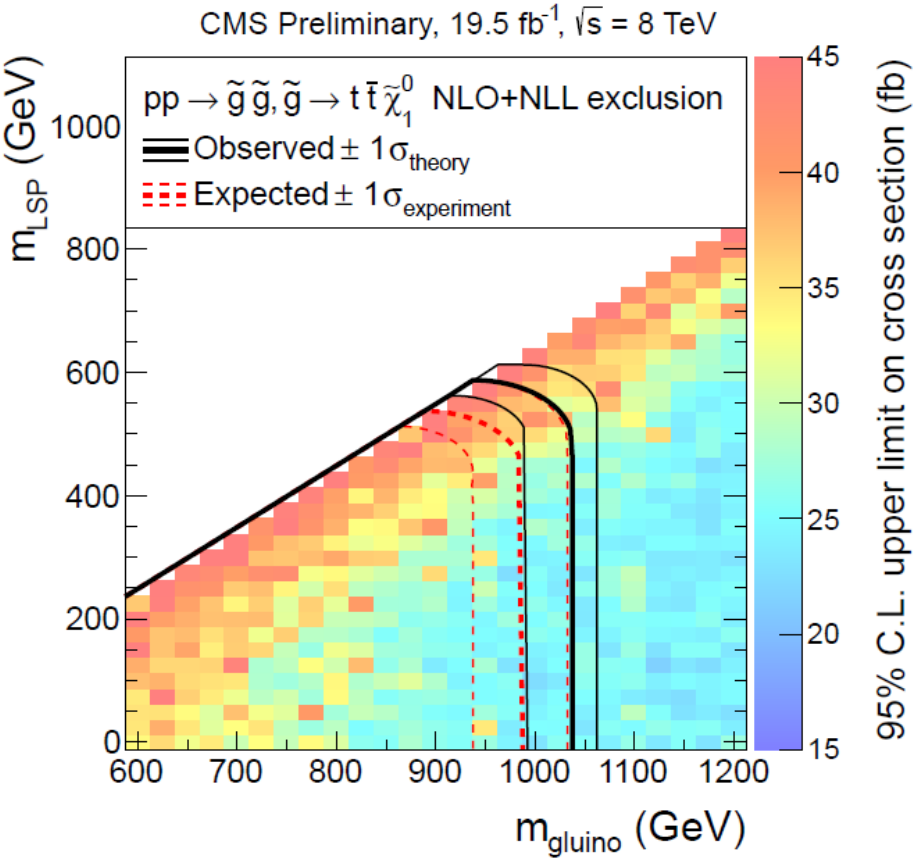
Fair agreement between SM predicted backgrounds and data

Gluino pair calling OFF shell stop

CMS-SUS-13-008



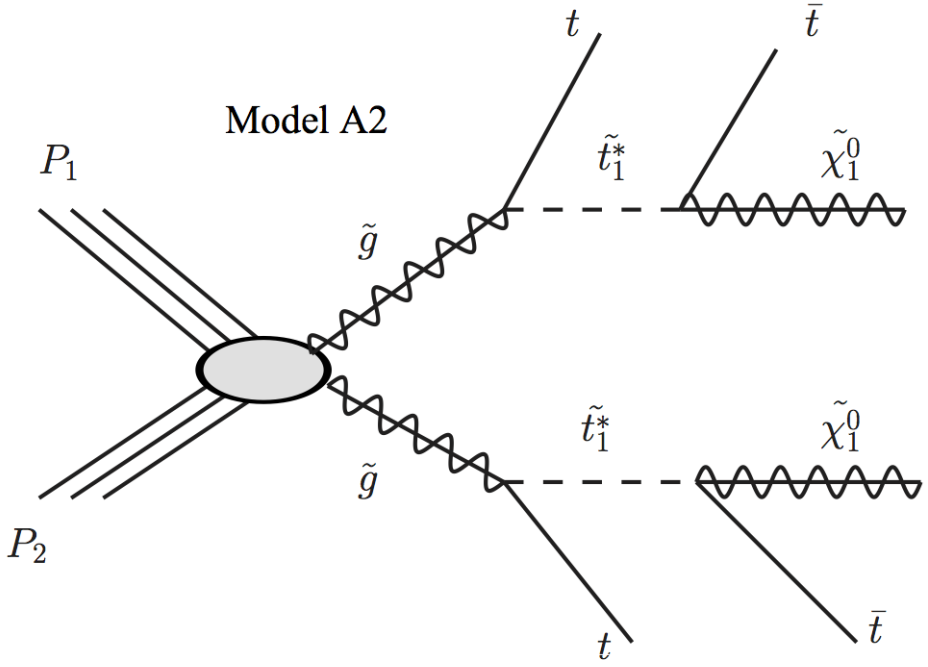
Gluino-pair production with decay in 4 top quarks and 2 lightest SUSY particles (LSP) via OFF-shell stop



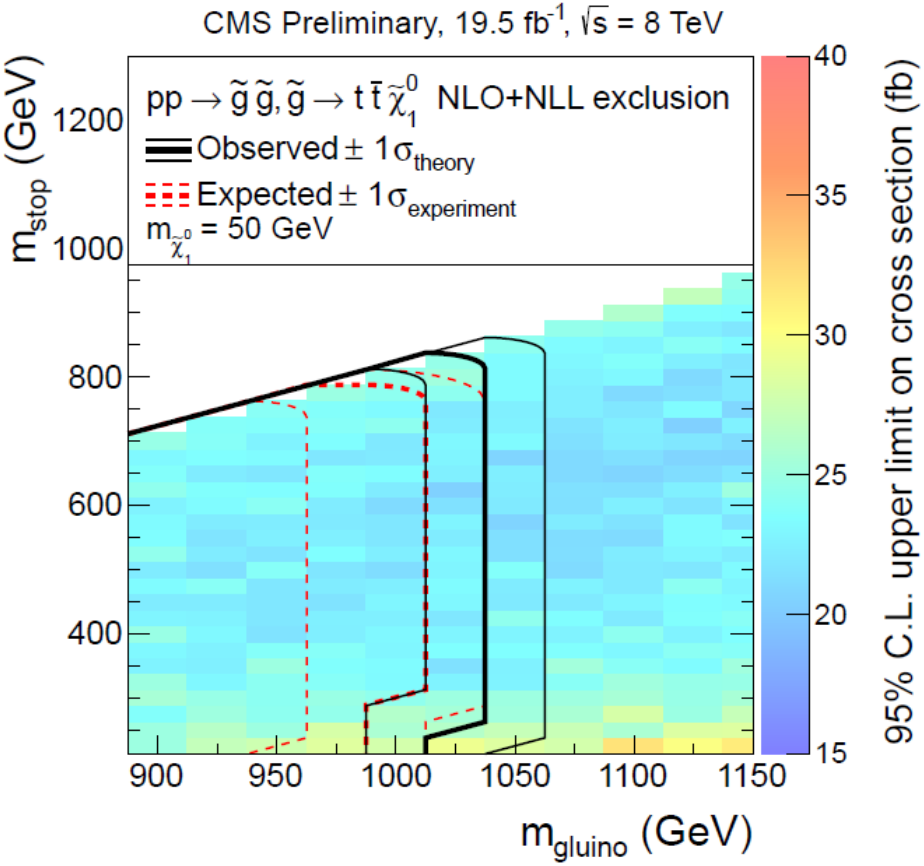
Lower limit on gluino mass = 975 GeV
if LSP mass range [0,500] GeV

Gluino pair calling ON shell stop

CMS-SUS-13-008



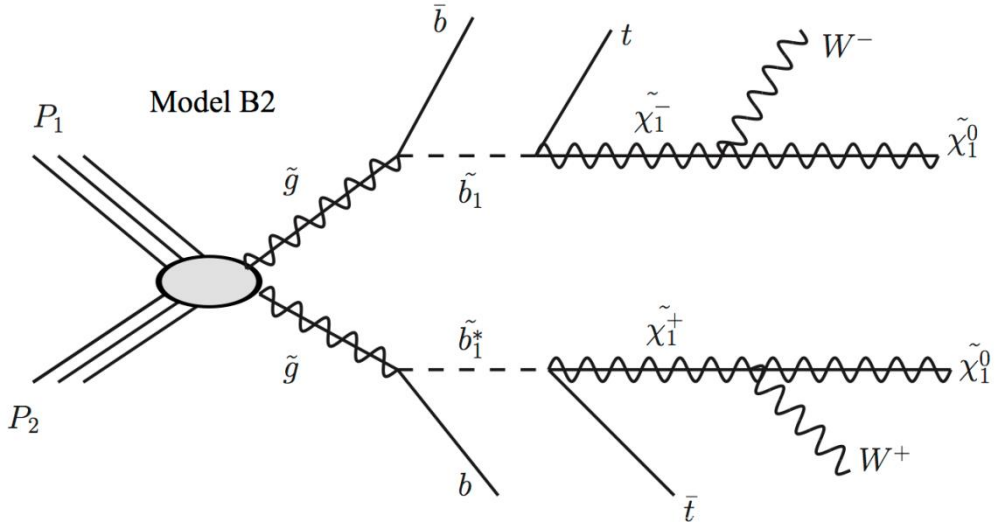
Gluino-pair production with decay in 4 top quarks and 2 lightest SUSY particles (LSP) via ON-shell stop



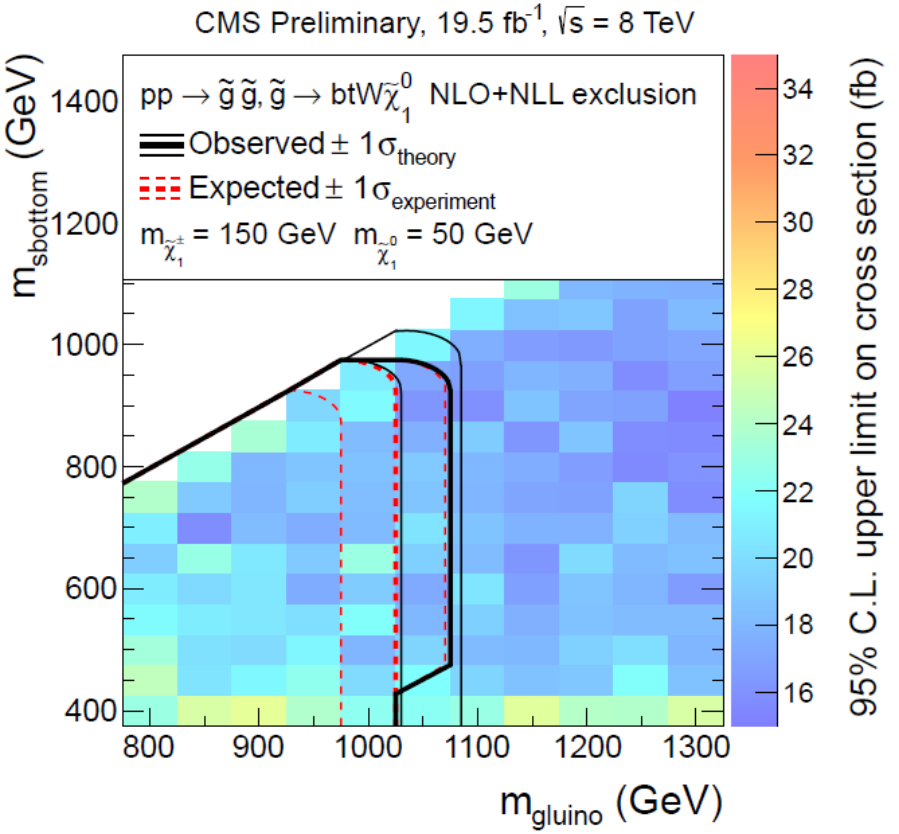
Lower limit on gluino mass = 1000 GeV
if stop mass range [250,800] GeV;
LSP mass fixed = 50 GeV

Gluino pair calling ON shell sbottom

CMS-SUS-13-008



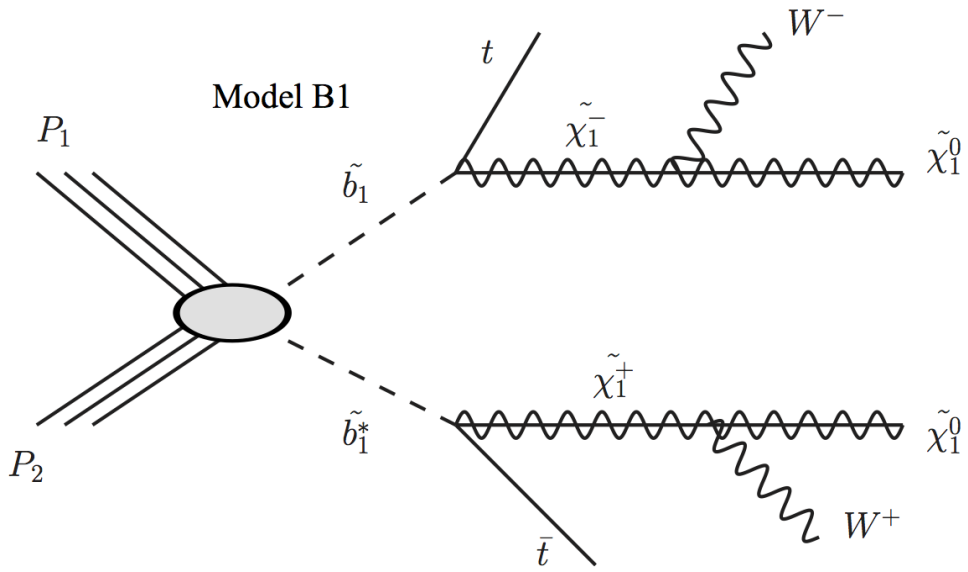
Gluino-pair production with decay to 2 bottom quarks, 2 top quarks, 2 W bosons, 2 lightest SUSY particles (LSP) via on-shell sbottom



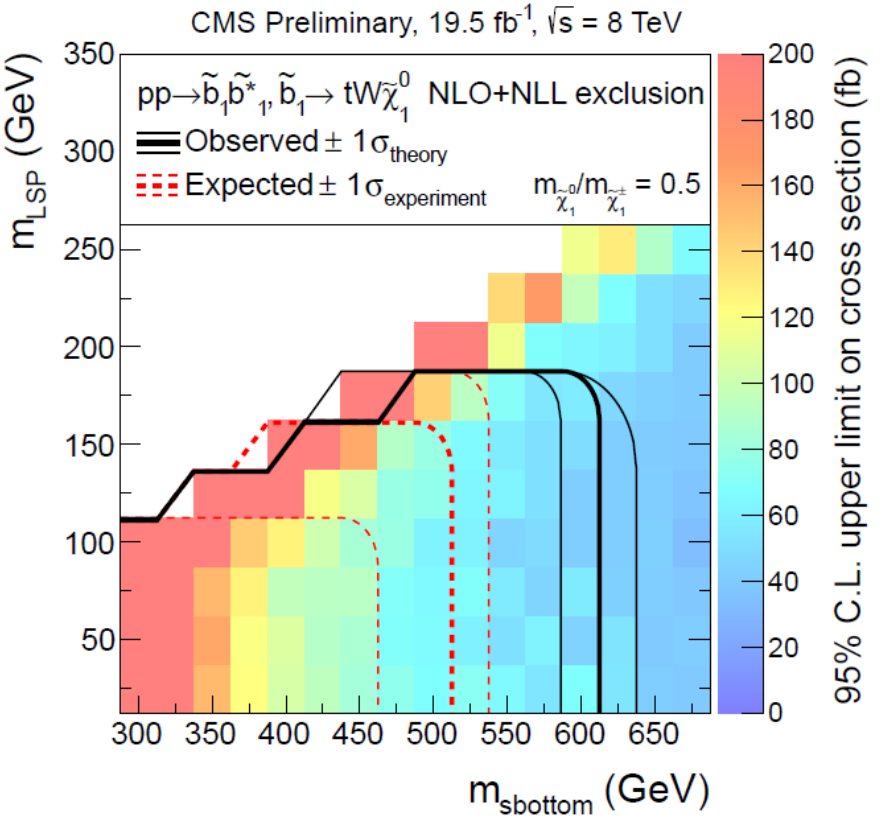
Lower limit on gluino mass = 1000 GeV
in sbottom mass range [400,950] GeV;
chargino mass fixed = 150 GeV
LSP mass fixed = 50 GeV

Sbottom with top and charginos

CMS-SUS-13-008



Direct sbottom-pair production with decay to 2 top quarks, 2 W bosons, 2 lightest SUSY particles (LSP)

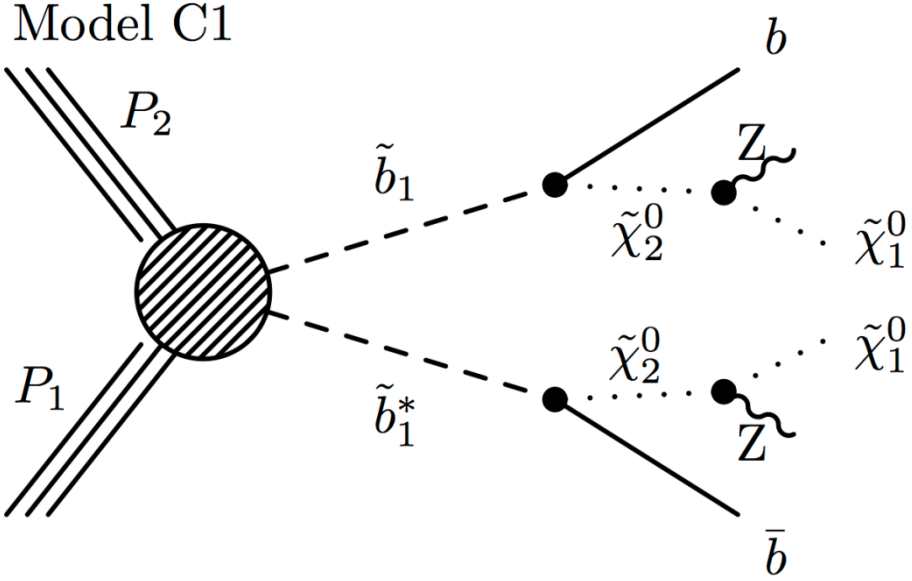


Lower limit on sbottom mass = 575 GeV in LSP mass range [25,150] GeV; ratio between neutralino and chargino mass fixed =0.5

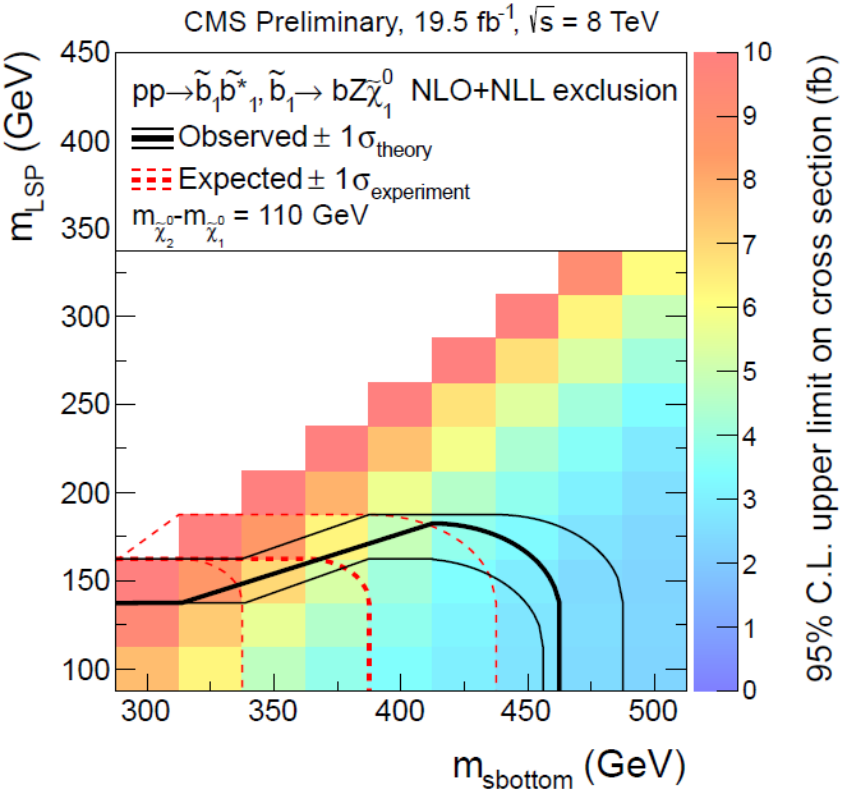
Sbottom with Z

CMS-SUS-13-008

Model C1



Direct sbottom-pair production with decay to 2 bottom quarks, 2 Z bosons, 2 lightest SUSY particles (LSP)

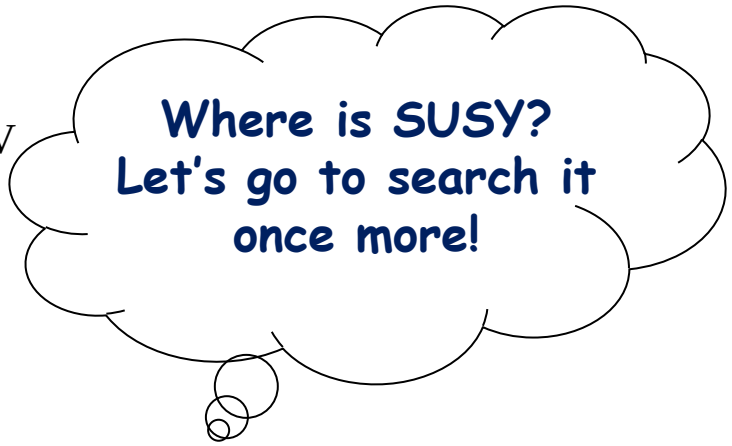


Lower limit on sbottom mass = 450 GeV in LSP mass range [100,125] GeV; mass difference between LSP and neutralino fixed = 110 GeV

Conclusions

- Results in multilepton events coming from full 2012 dataset are shown and two model-indipendent searches are presented.
- No significant excess has been found.
- Intepretations in several chosen SUSY models are proposed.
- More new results coming…stay tuned!

Gluinos decay to top pairs excluded for masses up to 975 GeV
Neutralinos decay to virtual stop excluded for masses up to 900 GeV
Gluinos decay to stops excluded for masses up to 1 TeV
Gluinos decay to sbottoms excluded for masses up to 1 TeV
Sbottom excluded for masses up to 450 GeV, if it goes to bottom
Sbottom excluded for masses up to 575 GeV, if it goes to top
…….
…….



Thank you !!!

CMS references

Search for supersymmetry in pp collisions at 8 TeV in events with three leptons and at least one b-tagged jet
SUS-13-008 PAS-only-PUB
Notes: AN-2012/433
CDS Record: 1547560

A search for anomalous production of events with three or more leptons
in 19.5 /fb of 8 TeV LHC data
SUS-13-002 PAS PUB
Notes: AN-2012/343, AN-2012/342, AN-2012/257

Back up slides

A search for anomalous production of events with three or more leptons

CMS-SUS-13-002

Results I

CMS-SUS-13-002

Selection 4 Lepton Results		E_T^{miss}	$N(\tau_h)=0$, $N_{b-jets}=0$ obs	exp	$N(\tau_h)=1$, $N_{b-jets}=0$ obs	exp	$N(\tau_h)=0$, $N_{b-jets}\geq 1$ obs	exp	$N(\tau_h)=1$, $N_{b-jets}\geq 1$ obs	exp
OSSF0 $H_T > 200$	NA	(100,∞)	0	0.01 ± 0.03	0	0.01 ± 0.06	0	0.02 ± 0.04	0	0.11 ± 0.08
OSSF0 $H_T > 200$	NA	(50,100)	0	0 ± 0.02	0	0.01 ± 0.06	0	0 ± 0.03	0	0.12 ± 0.07
OSSF0 $H_T > 200$	NA	(0,50)	0	$1e\text{-}05 \pm 0.02$	0	0.07 ± 0.1	0	0 ± 0.02	0	0.02 ± 0.02
OSSF1 $H_T > 200$	off-Z	(100,∞)	0	0.005 ± 0.02	1	0.25 ± 0.11	0	0.13 ± 0.08	0	0.12 ± 0.12
OSSF1 $H_T > 200$	on-Z	(100,∞)	1	0.1 ± 0.06	0	0.5 ± 0.27	0	0.42 ± 0.22	0	0.42 ± 0.19
OSSF1 $H_T > 200$	off-Z	(50,100)	0	0.07 ± 0.06	1	0.29 ± 0.13	0	0.04 ± 0.04	0	0.23 ± 0.13
OSSF1 $H_T > 200$	on-Z	(50,100)	0	0.23 ± 0.11	1	0.7 ± 0.31	0	0.23 ± 0.13	1	0.34 ± 0.16
OSSF1 $H_T > 200$	off-Z	(0,50)	0	0.02 ± 0.03	0	0.27 ± 0.12	0	0.03 ± 0.04	0	0.31 ± 0.15
OSSF1 $H_T > 200$	on-Z	(0,50)	0	0.2 ± 0.08	0	1.3 ± 0.47	0	0.06 ± 0.04	1	0.49 ± 0.19
OSSF2 $H_T > 200$	off-Z	(100,∞)	0	0.01 ± 0.02	0	0 ± 0	0	0.01 ± 0.06	0	0 ± 0
OSSF2 $H_T > 200$	on-Z	(100,∞)	1	0.15 ± 0.16	0	0 ± 0	0	0.34 ± 0.18	0	0 ± 0
OSSF2 $H_T > 200$	off-Z	(50,100)	0	0.03 ± 0.02	0	0 ± 0	0	0.13 ± 0.09	0	0 ± 0
OSSF2 $H_T > 200$	on-Z	(50,100)	0	0.8 ± 0.4	0	0 ± 0	0	0.36 ± 0.19	0	0 ± 0
OSSF2 $H_T > 200$	off-Z	(0,50)	1	0.27 ± 0.13	0	0 ± 0	0	0.08 ± 0.05	0	0 ± 0
OSSF2 $H_T > 200$	on-Z	(0,50)	5	7.4 ± 3.5	0	0 ± 0	2	0.8 ± 0.4	0	0 ± 0

Table 1: Results from 19.5 fb^{-1} of 2012 data. The labels going down the side refer to whether or not there are OSSF pairs, whether or not $Z \to \ell^+\ell^-$ was excluded (below-Z means $m_{ll} <$ 75 GeV, above-Z means $m_{ll} > 105$ GeV, on-Z means m_{ll} between 75 and 105 GeV), and the H_T and E_T^{miss} requirements. Labels along the top of the table give the number of τ_h candidates, 0 or 1 and the number of b-jets which is 0 or ≥1. All channels are exclusive. The channels shown in the table are for displaying purposes only. Finer E_T^{miss} channels are used for the fitting procedure and for setting the limits.

Results II

CMS-SUS-13-002

Selection 4 Lepton Results		E_T^{miss}	N(τ_h)=0, N_{b-jets}=0 obs	exp	N(τ_h)=1, N_{b-jets}=0 obs	exp	N(τ_h)=0, $N_{b-jets}\geq1$ obs	exp	N(τ_h)=1, $N_{b-jets}\geq1$ obs	exp
OSSF0 $H_T < 200$	NA	(100,∞)	0	0.11 ± 0.08	0	0.17 ± 0.1	0	0.03 ± 0.04	0	0.04 ± 0.04
OSSF0 $H_T < 200$	NA	(50,100)	0	0.01 ± 0.03	2	0.7 ± 0.33	0	0 ± 0.02	0	0.28 ± 0.16
OSSF0 $H_T < 200$	NA	(0,50)	0	0.01 ± 0.02	1	0.7 ± 0.3	0	0.001 ± 0.02	0	0.13 ± 0.08
OSSF1 $H_T < 200$	off-Z	(100,∞)	0	0.06 ± 0.04	3	0.6 ± 0.24	0	0.02 ± 0.04	0	0.32 ± 0.2
OSSF1 $H_T < 200$	on-Z	(100,∞)	1	0.5 ± 0.18	2	2.5 ± 0.5	1	0.38 ± 0.2	0	0.21 ± 0.1
OSSF1 $H_T < 200$	off-Z	(50,100)	0	0.18 ± 0.06	4	2.1 ± 0.5	0	0.16 ± 0.08	1	0.45 ± 0.24
OSSF1 $H_T < 200$	on-Z	(50,100)	2	1.2 ± 0.34	9	9.6 ± 1.6	2	0.42 ± 0.23	0	0.5 ± 0.16
OSSF1 $H_T < 200$	off-Z	(0,50)	2	0.46 ± 0.18	15	7.5 ± 2	0	0.09 ± 0.06	0	0.7 ± 0.31
OSSF1 $H_T < 200$	on-Z	(0,50)	4	3 ± 0.8	41	40 ± 10	1	0.31 ± 0.15	2	1.5 ± 0.47
OSSF2 $H_T < 200$	off-Z	(100,∞)	0	0.04 ± 0.03	0	0 ± 0	0	0.05 ± 0.04	0	0 ± 0
OSSF2 $H_T < 200$	on-Z	(100,∞)	0	0.34 ± 0.15	0	0 ± 0	0	0.46 ± 0.25	0	0 ± 0
OSSF2 $H_T < 200$	off-Z	(50,100)	2	0.18 ± 0.13	0	0 ± 0	0	0.02 ± 0.03	0	0 ± 0
OSSF2 $H_T < 200$	on-Z	(50,100)	4	3.9 ± 2.5	0	0 ± 0	0	0.5 ± 0.21	0	0 ± 0
OSSF2 $H_T < 200$	off-Z	(0,50)	7	8.9 ± 2.4	0	0 ± 0	1	0.23 ± 0.09	0	0 ± 0
OSSF2 $H_T < 200$	on-Z	(0,50)	*156	159 ± 34	0	0 ± 0	4	2.9 ± 0.8	0	0 ± 0

Table 2: Results from 19.5 fb^{-1} of 2012 data. The labels going down the side refer to whether or not there are OSSF pairs, whether or not $Z \to \ell^+\ell^-$ was excluded (below-Z means $m_{ll} < 75\,GeV$, above-Z means $m_{ll} > 105\,GeV$, on-Z means m_{ll} between 75 and 105 GeV), and the H_T and E_T^{miss} requirements. Labels along the top of the table give the number of τ_h candidates, 0 or 1 and the number of b-jets which is 0 or ≥1. All channels are exclusive. The channels shown in the table are for displaying purposes only. Finer E_T^{miss} channels are used for the fitting procedure and for setting the limits.

Results III

CMS-SUS-13-002

Selection 3 Lepton Results		E_T^{miss}	$N(\tau_h)=0$, $N_{b-jets}=0$ obs	exp	$N(\tau_h)=1$, $N_{b-jets}=0$ obs	exp	$N(\tau_h)=0$, $N_{b-jets}\geq 1$ obs	exp	$N(\tau_h)=1$, $N_{b-jets}\geq 1$ obs	exp
OSSF0 $H_T > 200$	NA	(100,∞)	5	3.7 ± 1.6	35	33 ± 14	1	5.5 ± 2.2	47	61 ± 30
OSSF0 $H_T > 200$	NA	(50,100)	3	3.5 ± 1.4	34	36 ± 16	8	7.7 ± 2.7	82	91 ± 46
OSSF0 $H_T > 200$	NA	(0,50)	4	2.1 ± 0.8	25	25 ± 9.7	1	3.6 ± 1.5	52	59 ± 29
OSSF1 $H_T > 200$	above-Z	(100,∞)	5	3.6 ± 1.2	2	10 ± 4.8	3	4.7 ± 1.6	19	22 ± 11
OSSF1 $H_T > 200$	below-Z	(100,∞)	7	9.7 ± 3.3	18	14 ± 6.4	8	9.1 ± 3.4	21	23 ± 11
OSSF1 $H_T > 200$	on-Z	(100,∞)	39	61 ± 23	17	15 ± 4.9	9	14 ± 4.4	10	12 ± 5.8
OSSF1 $H_T > 200$	above-Z	(50,100)	4	5 ± 1.6	14	11 ± 5.2	6	6.8 ± 2.4	32	30 ± 15
OSSF1 $H_T > 200$	below-Z	(50,100)	10	11 ± 3.8	24	19 ± 6.4	10	9.9 ± 3.7	25	32 ± 16
OSSF1 $H_T > 200$	on-Z	(50,100)	78	80 ± 32	70	50 ± 11	22	22 ± 6.3	36	24 ± 9.8
OSSF1 $H_T > 200$	above-Z	(0,50)	3	7.3 ± 2	41	33 ± 8.7	4	5.3 ± 1.5	15	23 ± 11
OSSF1 $H_T > 200$	below-Z	(0,50)	26	25 ± 6.8	110	86 ± 23	5	10 ± 2.5	24	26 ± 11
OSSF1 $H_T > 200$	on-Z	(0,50)	*135	127 ± 41	542	543 ± 159	31	32 ± 6.5	86	75 ± 19

Table 3: Results from 19.5 fb^{-1} of 2012 data. The labels going down the side refer to whether or not there are OSSF pairs, whether or not $Z \to \ell^+\ell^-$ was excluded (below-Z means $m_{ll} < 75$ GeV, above-Z means $m_{ll} > 105$ GeV, on-Z means m_{ll} between 75 and 105 GeV), and the H_T and E_T^{miss} requirements. Labels along the top of the table give the number of τ_h candidates, 0 or 1 and the number of b-jets which is 0 or ≥1. All channels are exclusive. The channels shown in the table are for displaying purposes only. Finer E_T^{miss} channels are used for the fitting procedure and for setting the limits.

Results IV

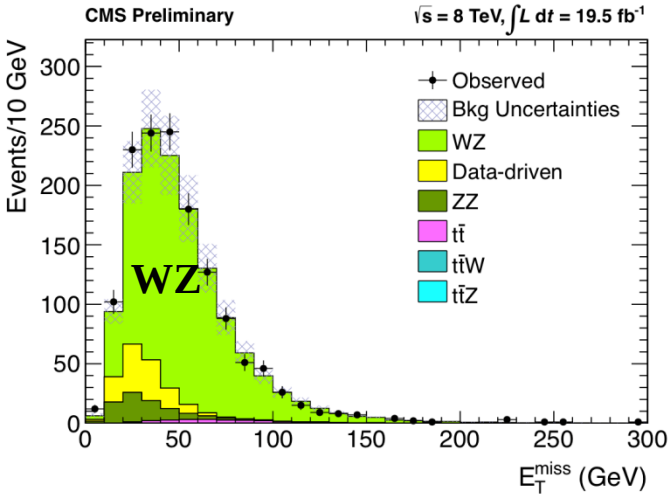
CMS-SUS-13-002

Selection 3 Lepton Results		E_T^{miss}	N(τ_h)=0, N_{b-jets}=0 obs	N(τ_h)=0, N_{b-jets}=0 exp	N(τ_h)=1, N_{b-jets}=0 obs	N(τ_h)=1, N_{b-jets}=0 exp	N(τ_h)=0, $N_{b-jets}\geq1$ obs	N(τ_h)=0, $N_{b-jets}\geq1$ exp	N(τ_h)=1, $N_{b-jets}\geq1$ obs	N(τ_h)=1, $N_{b-jets}\geq1$ exp
OSSF0 $H_T < 200$	NA	(100,∞)	7	11 ± 4.9	101	111 ± 54	13	10 ± 5.3	87	119 ± 61
OSSF0 $H_T < 200$	NA	(50,100)	35	38 ± 15	406	402 ± 152	29	26 ± 13	269	298 ± 151
OSSF0 $H_T < 200$	NA	(0,50)	53	51 ± 11	910	1035 ± 255	29	23 ± 10	237	240 ± 113
OSSF1 $H_T < 200$	above-Z	(100,∞)	18	13 ± 3.5	25	38 ± 18	10	6.5 ± 2.9	24	35 ± 18
OSSF1 $H_T < 200$	below-Z	(100,∞)	21	24 ± 9	41	50 ± 25	14	20 ± 10	42	54 ± 28
OSSF1 $H_T < 200$	on-Z	(100,∞)l	150	152 ± 26	39	48 ± 13	15	14 ± 4.8	19	23 ± 11
OSSF1 $H_T < 200$	above-Z	(50,100)	50	46 ± 9.7	169	139 ± 48	20	18 ± 8	85	93 ± 47
OSSF1 $H_T < 200$	below-Z	(50,100)	142	125 ± 27	353	355 ± 92	48	48 ± 23	140	133 ± 68
OSSF1 $H_T < 200$	on-Z	(50,100)	*773	777 ± 116	1276	1154 ± 306	56	47 ± 13	81	75 ± 32
OSSF1 $H_T < 200$	above-Z	(0,50)	178	196 ± 35	1676	1882 ± 540	17	18 ± 6.7	115	94 ± 42
OSSF1 $H_T < 200$	below-Z	(0,50)	510	547 ± 87	9939	8980 ± 2660	34	42 ± 11	226	228 ± 63
OSSF1 $H_T < 200$	on-Z	(0,50)	*3869	4105 ± 666	*50188	50162 ± 14984	*148	156 ± 24	906	925 ± 263

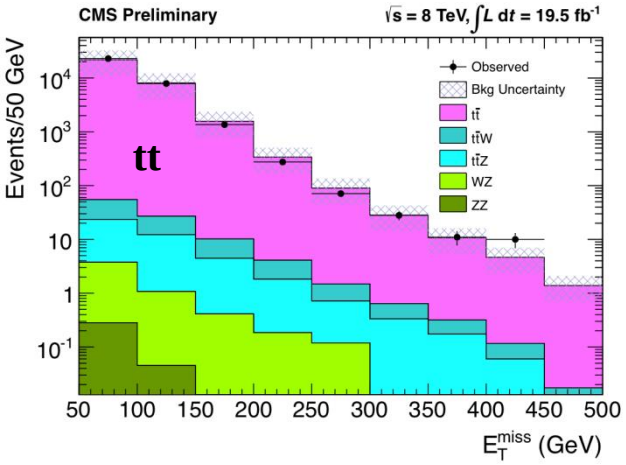
Table 4: Results from 19.5 fb^{-1} of 2012 data. The labels going down the side refer to whether or not there are OSSF pairs, whether or not $Z \to \ell^+\ell^-$ was excluded (below-Z means $m_{ll} <$ 75 GeV, above-Z means $m_{ll} > 105$ GeV, on-Z means m_{ll} between 75 and 105 GeV), and the H_T and E_T^{miss} requirements. Labels along the top of the table give the number of τ_h candidates, 0 or 1 and the number of b-jets which is 0 or ≥1. All channels are exclusive. The channels shown in the table are for displaying purposes only. Finer E_T^{miss} channels are used for the fitting procedure and for setting the limits.

Control region distributions

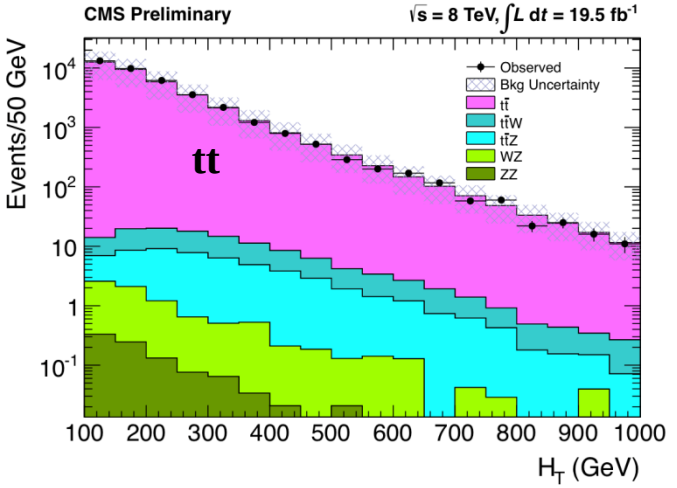
CMS-SUS-13-002



WZ control region
MET distribution



tt(bar) control region
MET and HT distributions



Uncertainties

CMS-SUS-13-002

Source of Uncertainty	Uncertainty
Luminosity	4.4%
PDF	14%
Renormalization Scale	10%
$E_{\mathrm{T}}^{\mathrm{miss}}$ Resolution/Smearing: $0-50\,\mathrm{GeV}, 50-100\,\mathrm{GeV}, >100\,\mathrm{GeV}$	(-3%, +4%, +4%)
Jet Energy Scale $W^{\pm}Z$	0.5% (WZ)
B-Tag Veto	0.1% (WZ), 6% ($t\bar{t}$)
Muon ID/Isolation at 10 (100) GeV	11% (0.2%)
Electron ID/Isolation at 10 (100) GeV	14 % (0.6%)
Tau ID/isolation at 10 (100) GeV	2%(1.1%)
$t\bar{t}$ cross-section/fake rate	50%
WZ normalization	6%
ZZ normalization	12%
Internal conversion fake rate	100%

Statistics dominated uncertainties

The results are used to place upper limits at 95% confidence level (CL) on the signal rate calculated using the modified frequentist CL method.

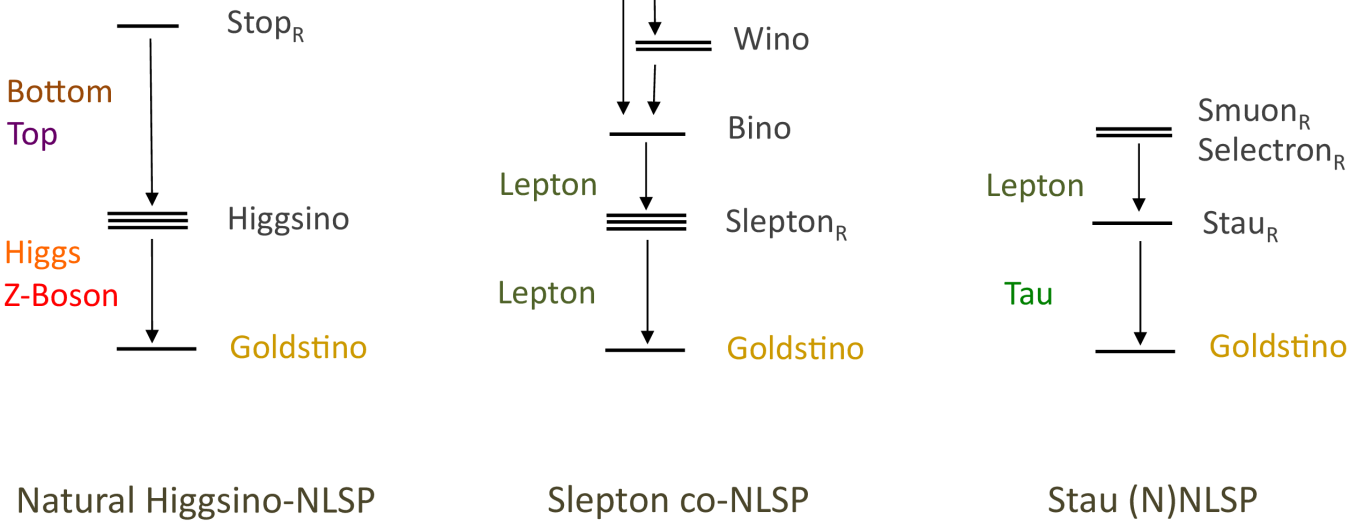
GMSB scenarios

CMS-SUS-13-002

GMSB = Gauge Mediated Supersymmetry Breaking

Gravitino is the lightest SUSY particle (LSP).

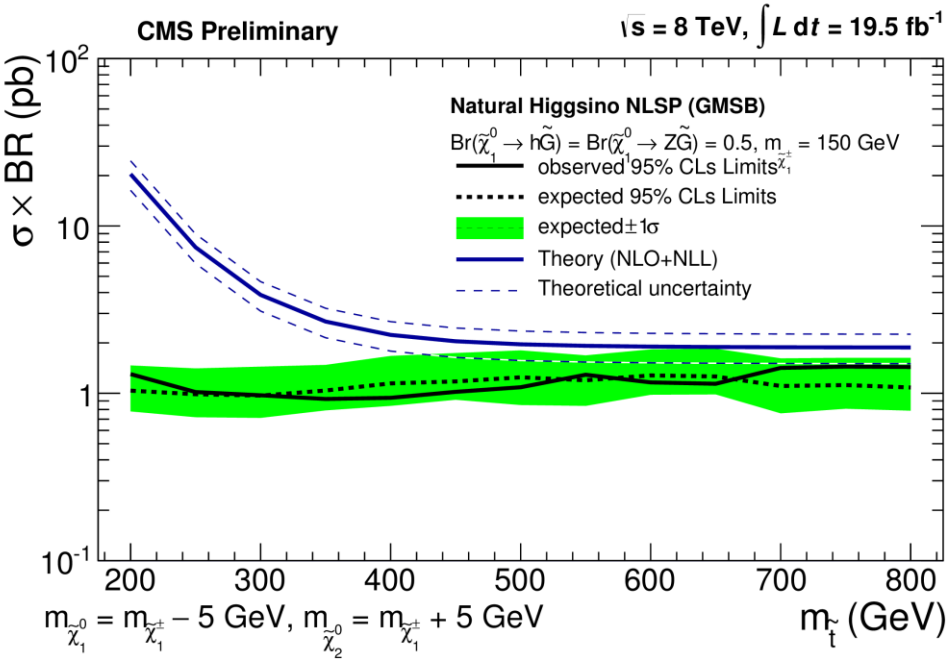
Mass spectra in 3 models

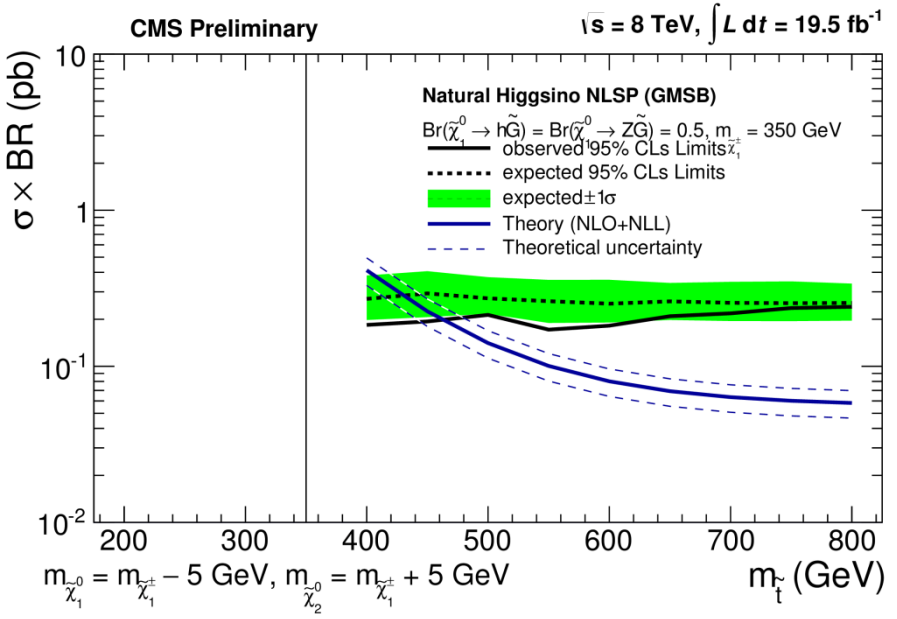


Natural Higgsino NLSP scenario

Gauge Mediated Supersymmetry Breaking (GMSB) model

CMS-SUS-13-002

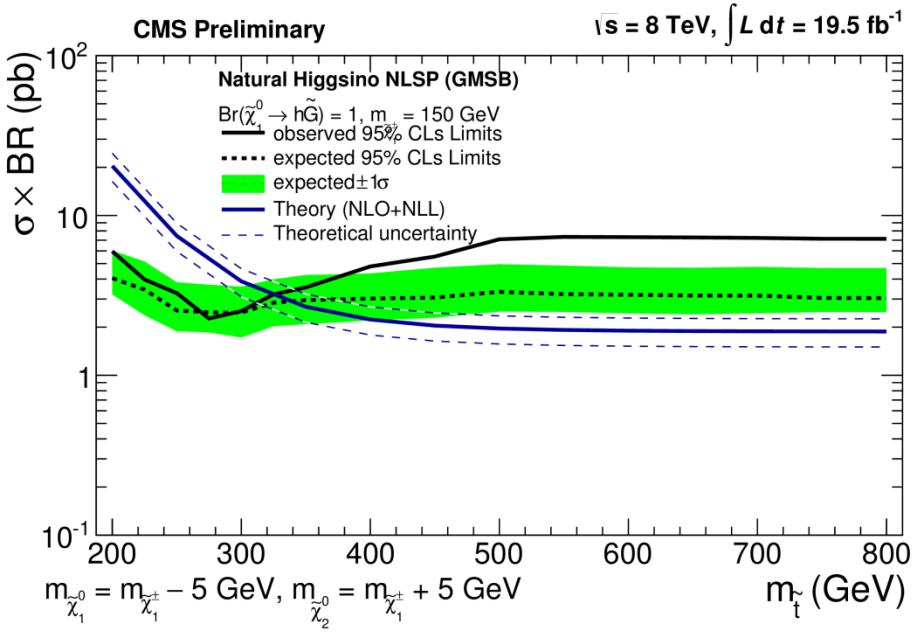


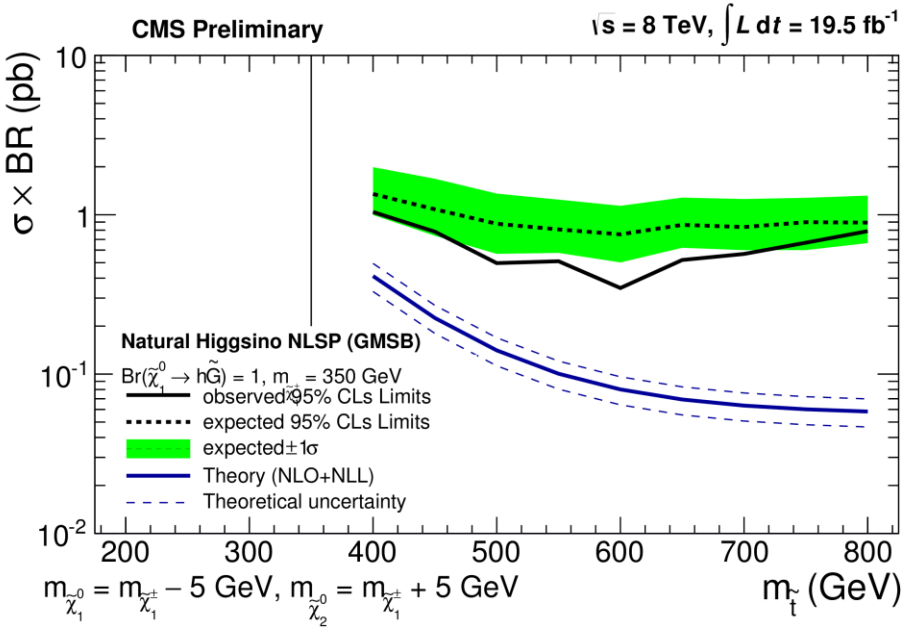


Natural Higgsino NLSP scenario

Gauge Mediated Supersymmetry Breaking (GMSB) model

CMS-SUS-13-002

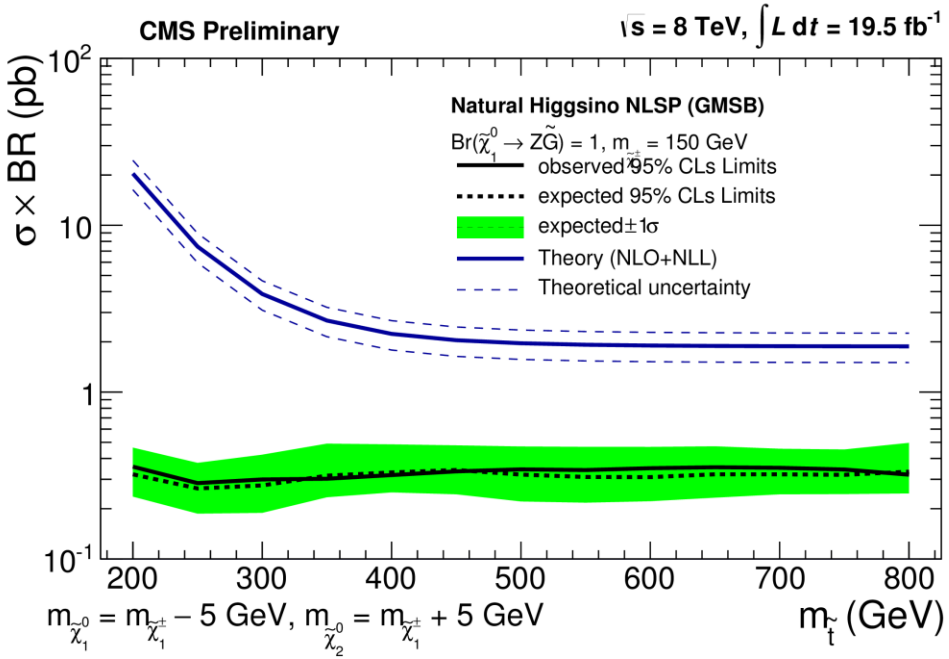


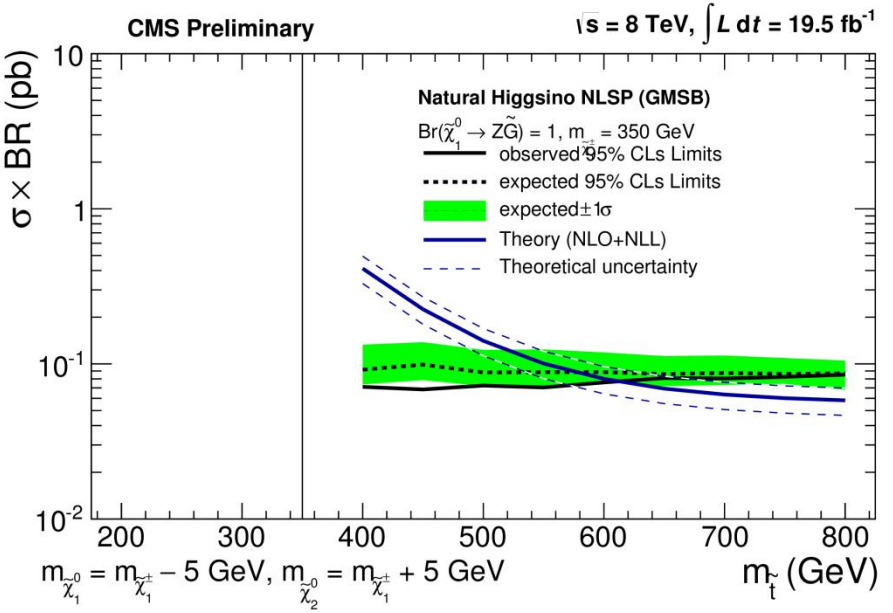


Natural Higgsino NLSP scenario

Gauge Mediated Supersymmetry Breaking (GMSB) model

CMS-SUS-13-002

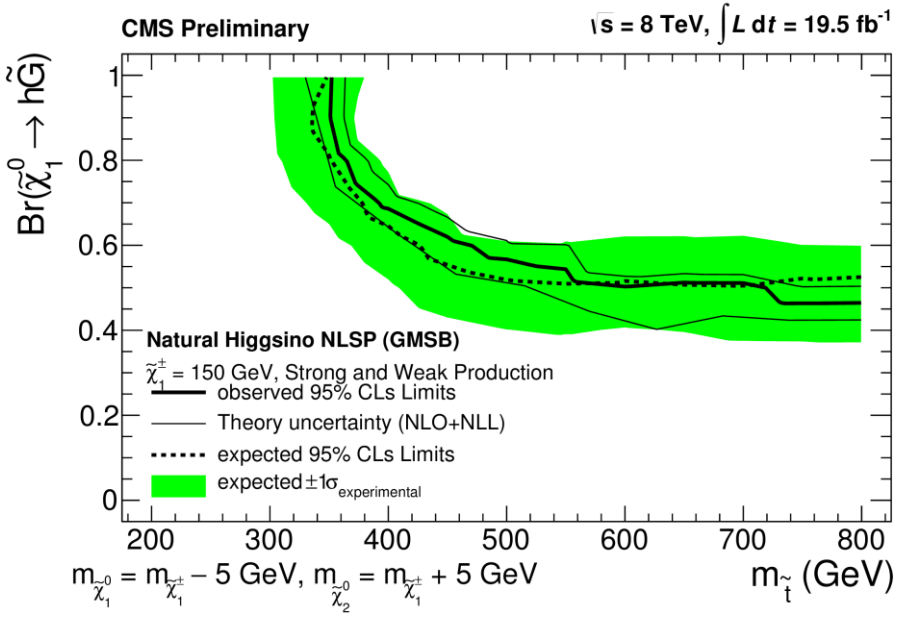


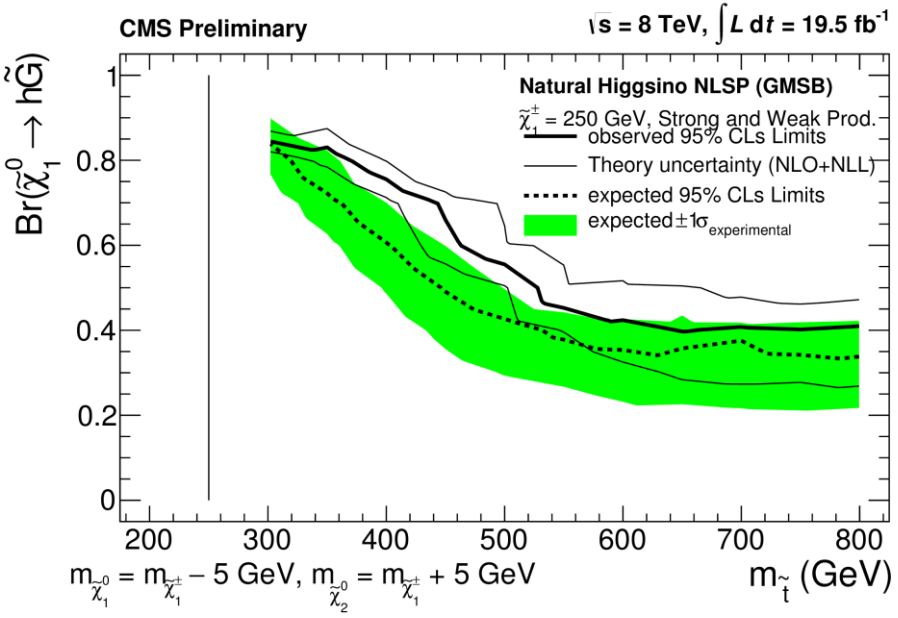


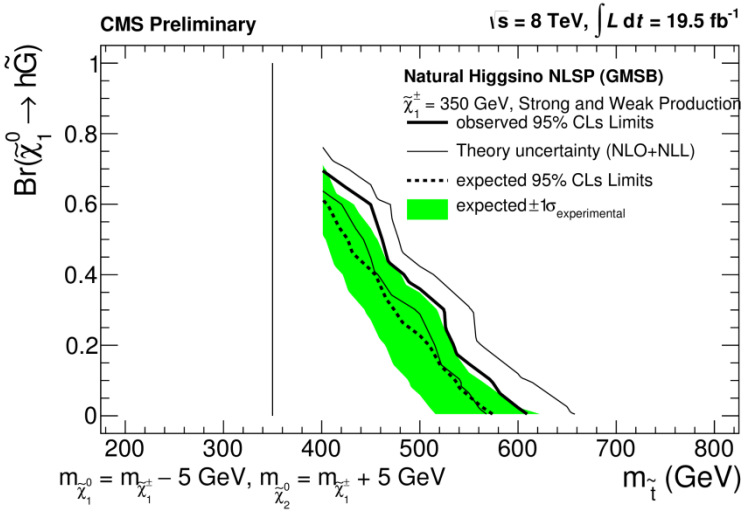
Natural Higgsino NLSP scenario

Gauge Mediated Supersymmetry Breaking (GMSB) model

CMS-SUS-13-002







Discrepancy studies

CMS-SUS-13-002

Categorie:

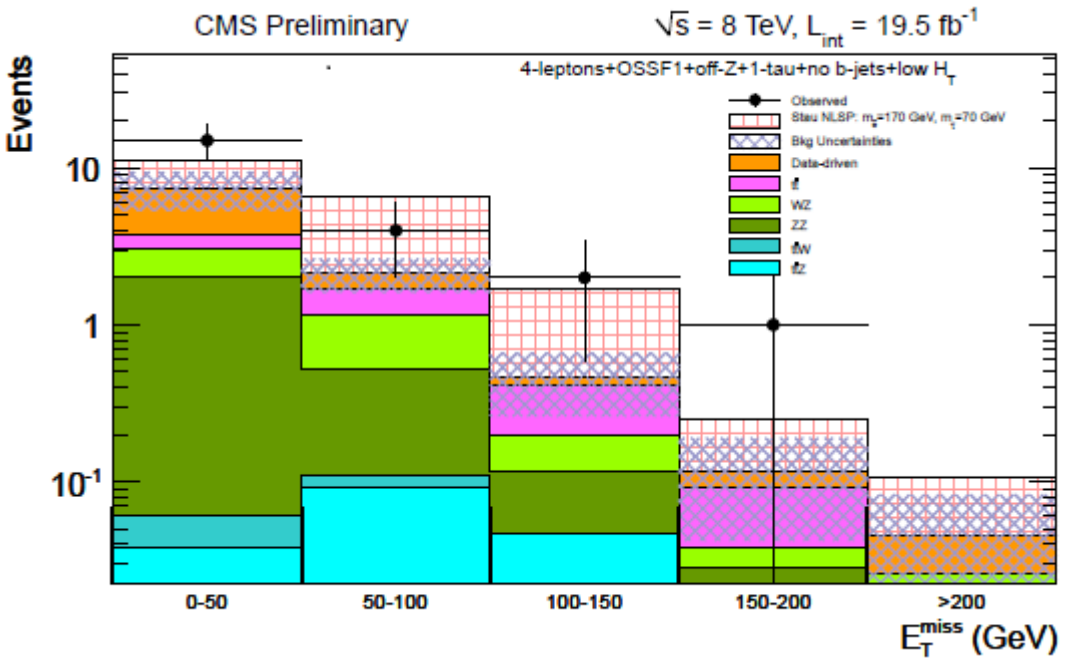
4 leptons, including 1 τ,

OSSF1, off-Z,

no b-tags, HT< 200 GeV

Observe = 22 events

Expected = 10 ± 2.4 events



Probability for 1 out of 64 categories to have as large a fluctuation ≈ 50 %

Probability for all bins in 1 out of 64 categories to have as large a fluctuation ≈ 5 %

Given that we search for new physics in 64 different categories of multi-lepton events, it is not surprising that we find one category with a large deviation between observed yield and expected SM background.

SMS scenarios

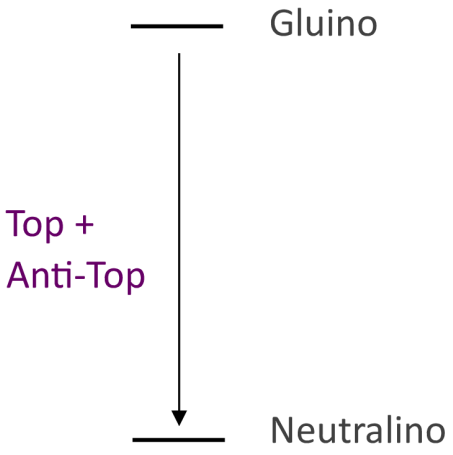
SMS = Simplified Models Space

CMS-SUS-13-002

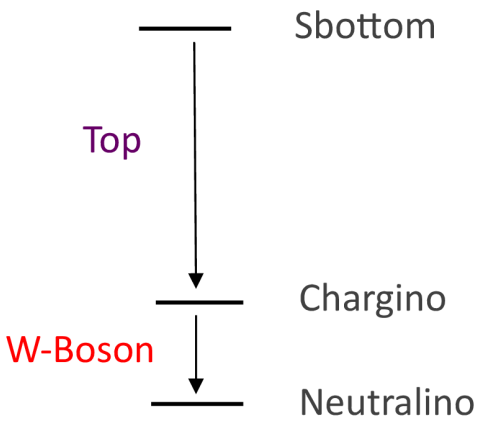
Neutralino is the lightest SUSY particle (LSP).

Mass spectra in 2 models

Production of partners of third generation quarks



T1tttt

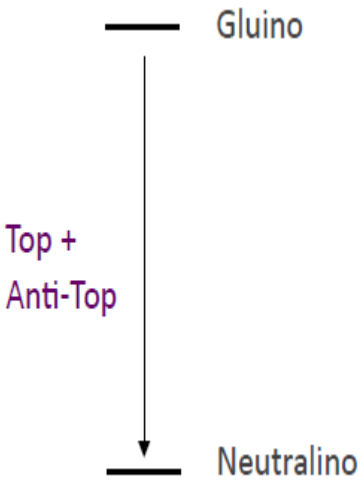


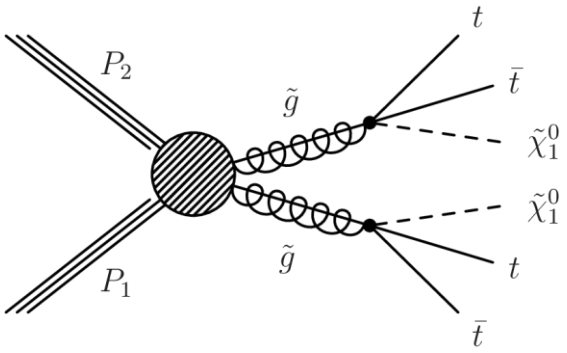
T6ttWW

Third generation scenario T1tttt

Simplified Models Space (SMS)

CMS-SUS-13-002

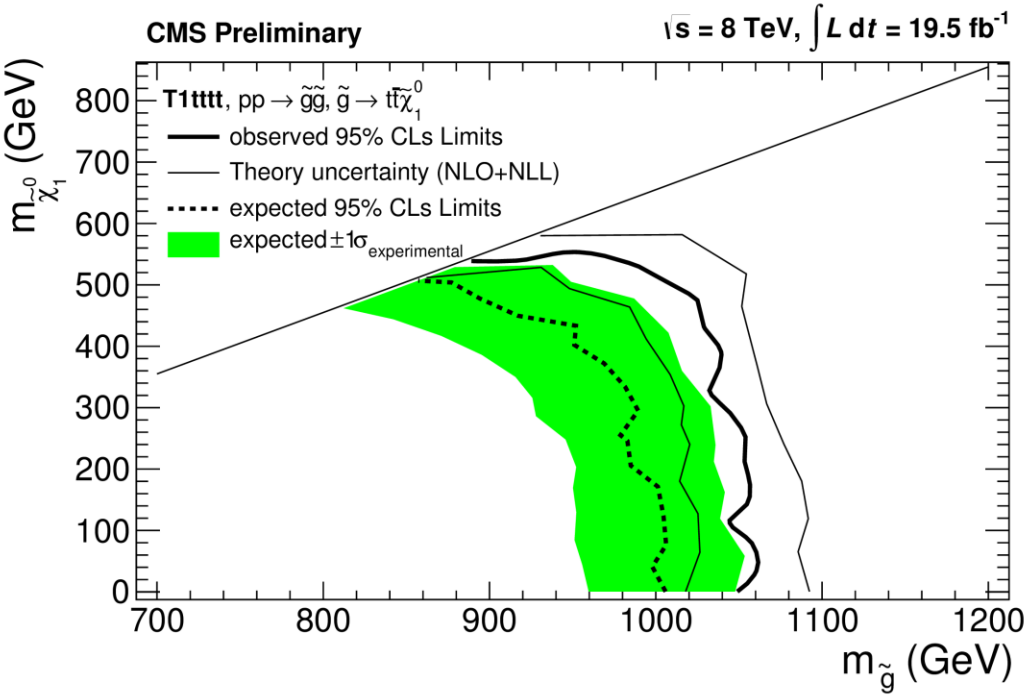




Third generation SUSY particles produced via gluino mediated stop production; gluinos decay in three bodies in SMS approssimation to tt(bar).

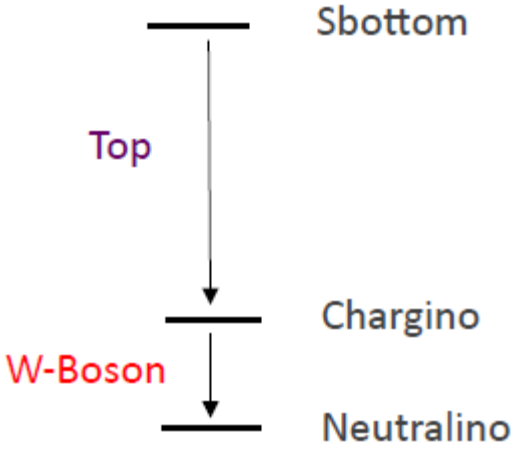
Signal populates b-tagged jets and high-HT channels.

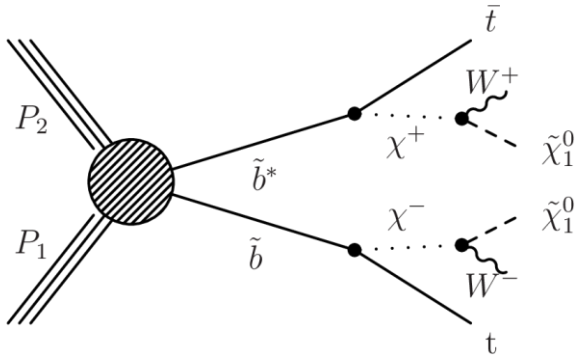
Exclusion limits in the gluino-neutralino mass plane



Third generation scenario T6ttWW

Simplified Models Space (SMS) model



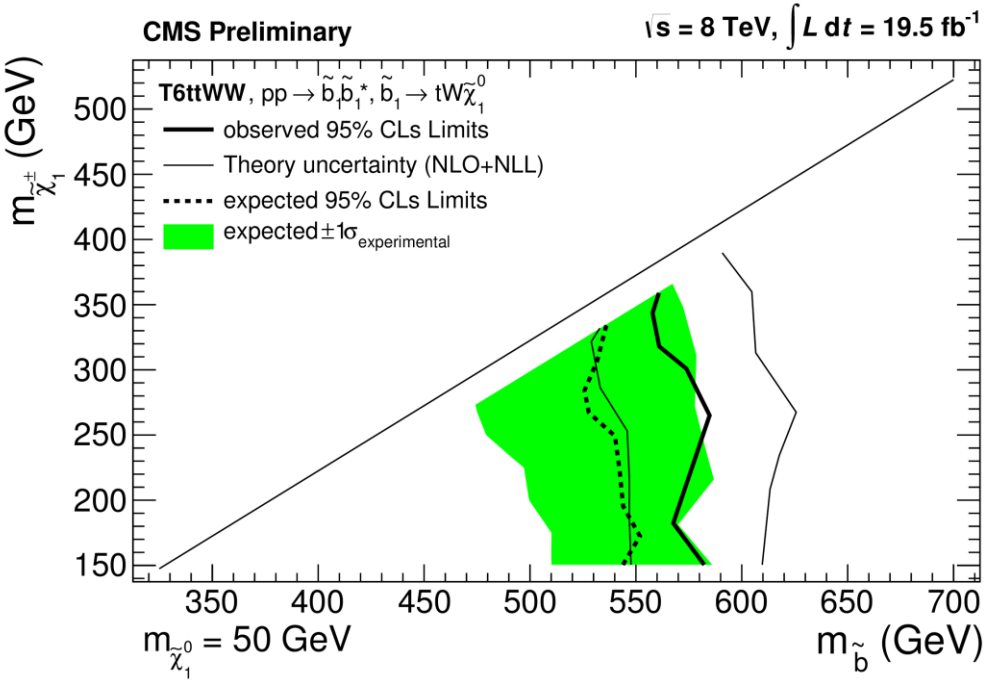


CMS-SUS-13-002

Direct sbottom pair production

Signal populates b-tagged jets channels.

Exclusion limits in the sbottom-chargino mass plane

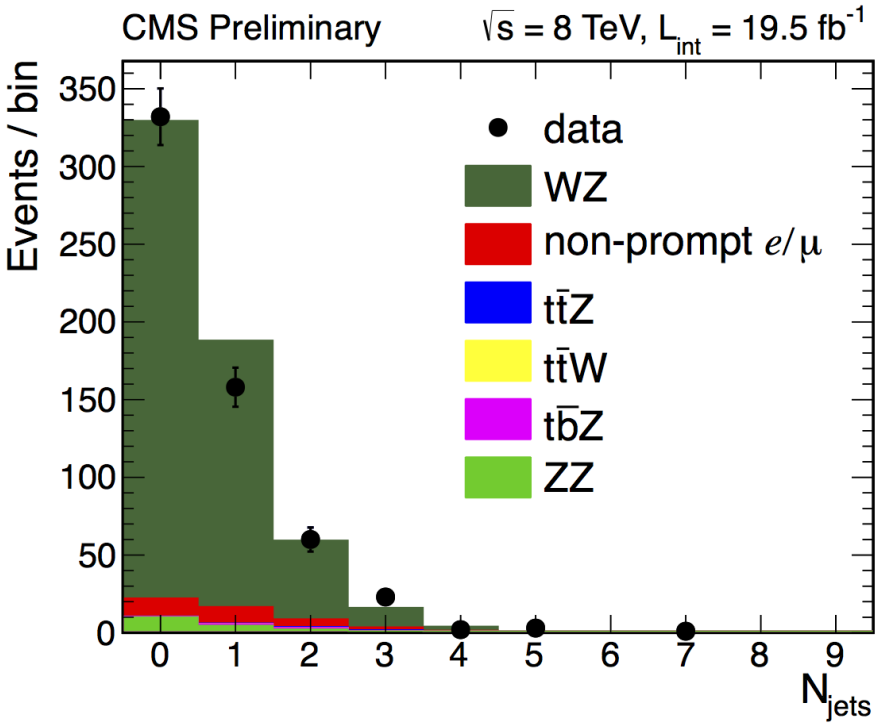


Search for supersymmetry in pp collisions at 8 TeV in events with three leptons and at least one b-tagged jet

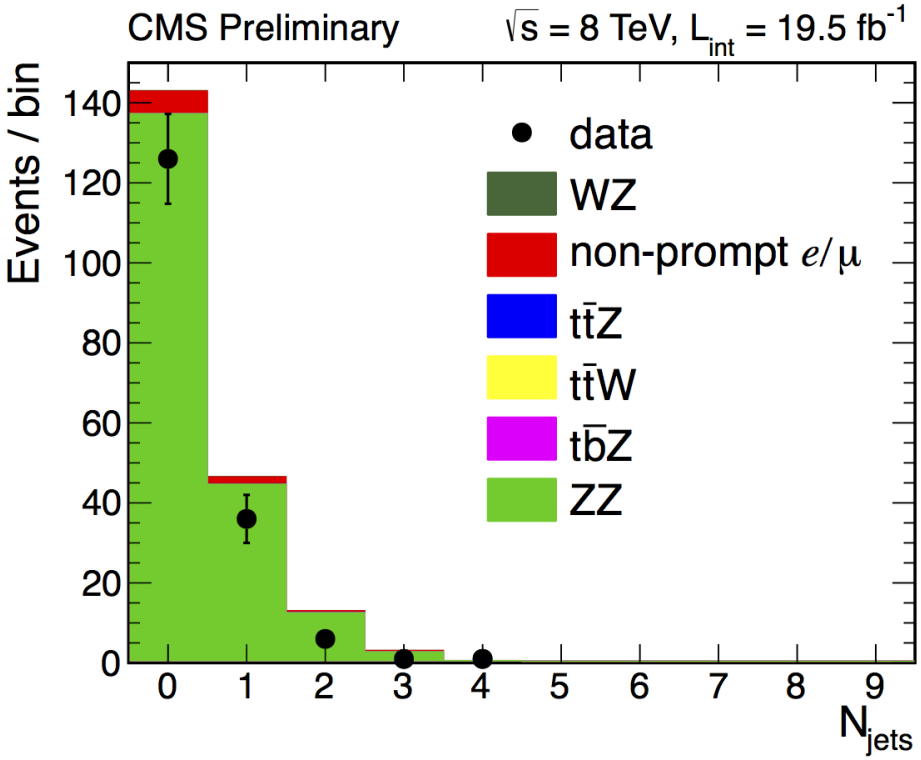
CMS-SUS-13-008

Control regions

CMS-SUS-13-008



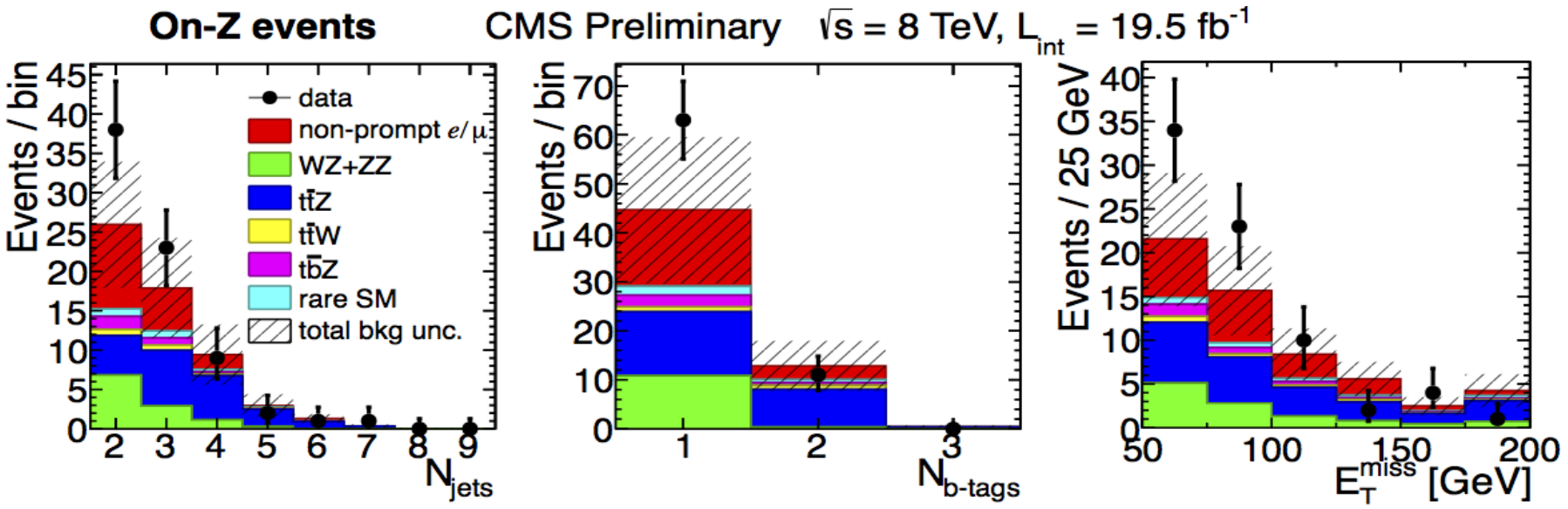
Jet multiplicity distributions for diboson events in WZ control regions in data and simulated event samples



Jet multiplicity distributions for diboson events in ZZ control regions in data and simulated event samples

Search regions distributions

CMS-SUS-13-008



Fair agreement between SM predicted backgrounds and data

Results in off Z regions

CMS-SUS-13-008

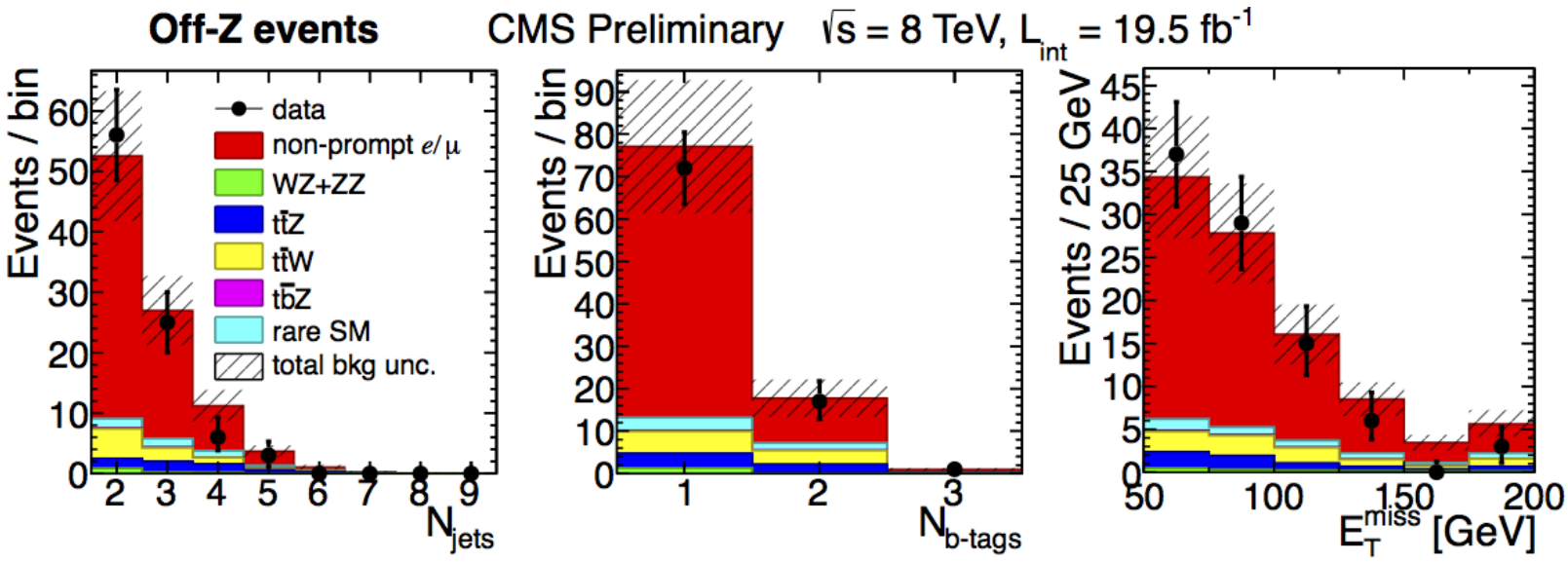
Searching results in different signal regions for events without a Z candidate (Off-Z)

$N_{b\text{-tags}}$	N_{jets}	E_T^{miss} (GeV)	$H_T < 200$ GeV		$H_T > 200$ GeV	
			Expected	Observed	Expected	Observed
1	2–3	50–100	33.3 ± 7.0	36	10.9 ± 2.4	9
		100–200	11.8 ± 2.6	13	9.0 ± 2.0	6
		≥200	0.33 ± 0.21	0	1.2 ± 0.4	0
	≥4	50–100	0.92 ± 0.36	2	5.3 ± 1.3	3
		100–200	0.10 ± 0.12	0	3.5 ± 1.0	3
		≥200	< 0.09	0	0.74 ± 0.31	0
2	2–3	50–100	4.7 ± 1.9	7	3.8 ± 1.1	7
		100–200	2.2 ± 0.7	1	1.9 ± 0.7	0
		≥200	0.22 ± 0.19	1	0.14 ± 0.13	0
	≥4	50–100	< 0.13	0	2.7 ± 0.8	1
		100–200	< 0.16	0	1.7 ± 0.6	0
		≥200	< 0.09	0	0.33 ± 0.18	0
≥3		50–100	< 0.09	0	0.56 ± 0.27	1
		100–200	< 0.12	0	0.17 ± 0.13	0
		≥200	< 0.09	0	0.20 ± 0.19	0

Fair agreement between data and SM predicted backgrounds

Search regions distributions

CMS-SUS-13-008

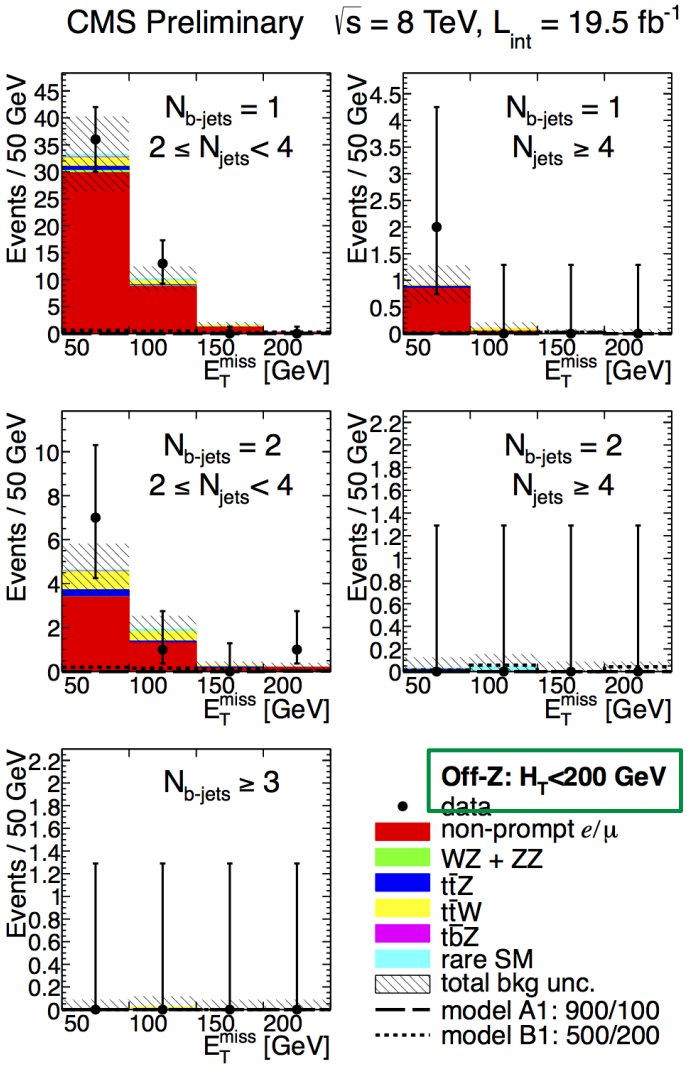


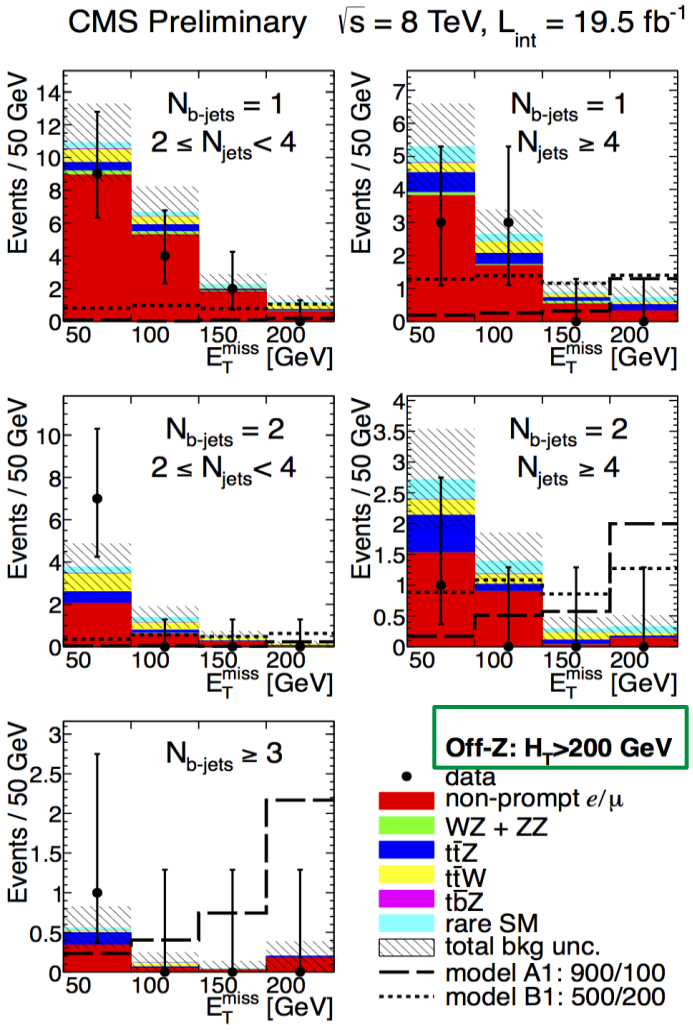
Fair agreement between SM predicted backgrounds and data

Search regions distributions

CMS-SUS-13-008

Off Z categories





Uncertainties

CMS-SUS-13-008

Source	Uncertainty, %
Luminosity	4.4
Modeling of lepton reconstruction, ID, I_{rel} based on Z-events	12
Jet energy scale	5–15
Unclustered energy and lepton effects on $E_{\mathrm{T}}^{\mathrm{miss}}$	5
Modeling of b-jet multiplicity	5–20
Trigger	5
Total systematic uncertainty	15–30

Statistics dominated uncertainties

The results are used to place upper limits at 95% confidence level (CL) on the signal rate calculated using the modified frequentist CL method.