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Search for Supersymmetry in the Single and Di-Lepton Final States at CMS

21st International conference on Supersymmetry and Unification of Fundamental Interactions, ICTP, Trieste

Marco - Andrea Buchmann
for the
CMS Collaboration

OUTLINE

Introduction

Same Sign Analysis

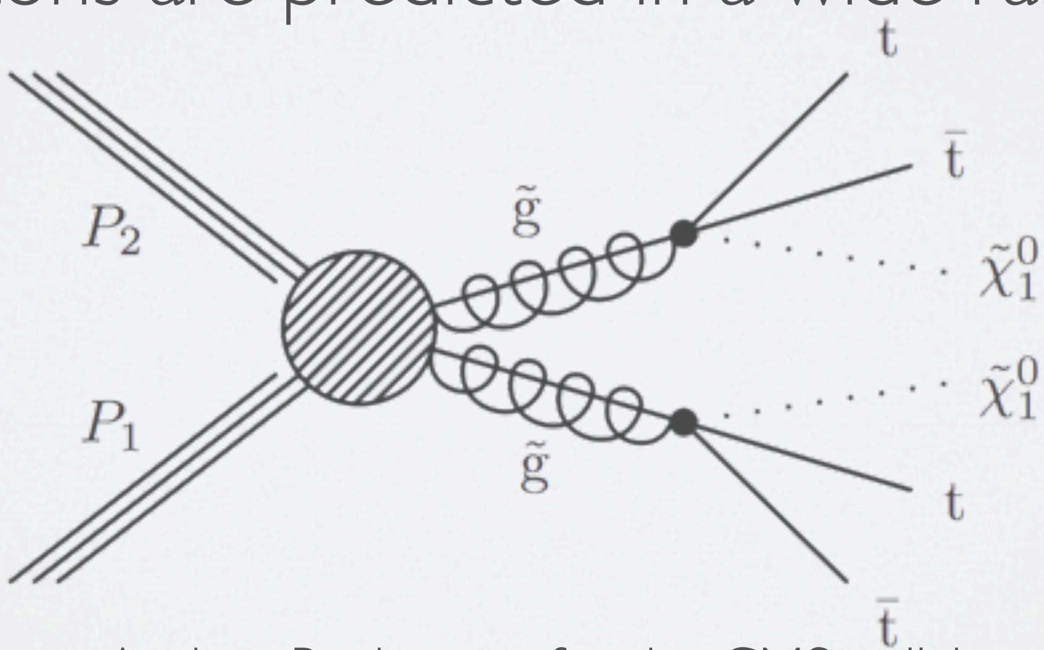
Single Lepton Analysis

Conclusions

INTRODUCTION

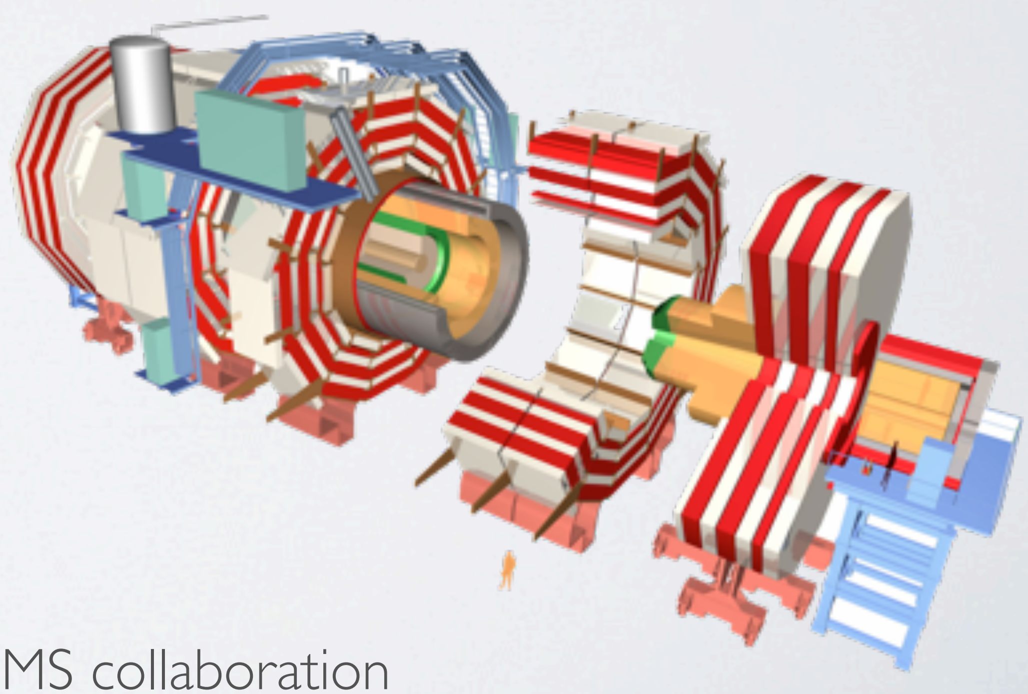
WHY A FINAL STATE WITH LEPTONS

- Leptons provide clear and robust signature
  - significantly suppress large Standard Model backgrounds (e.g. QCD)
  - measurement of leptons at CMS more precise than that of jets
- Di-lepton final states represent good compromise between background control and production rate
- Single lepton final states has larger rates
- Final states with leptons are predicted in a wide range of BSM models



ABOUT CMS

- CMS is a general purpose detector
- Different subsystems to measure particle properties to great precision in a large energy range
- Consists of the following layers
  - Silicon-based tracker
  - Scintillating crystal electromagnetic calorimeter
  - Sampling calorimeter for hadrons
  - Solenoid (3.8T !)
  - Large muon detectors
  - Return yoke of the magnet



CMS LEPTON SUSY SEARCHES

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

- SUSY can manifest itself in different ways in lepton final states with 1/2 l's:
  - same sign
  - opposite sign (Z-search and off-peak)
  - SingleLepton
- In the following, latest results will be shown not only for di-lepton final state but also single lepton final state, using the full 8 TeV dataset

SAME SIGN ANALYSIS

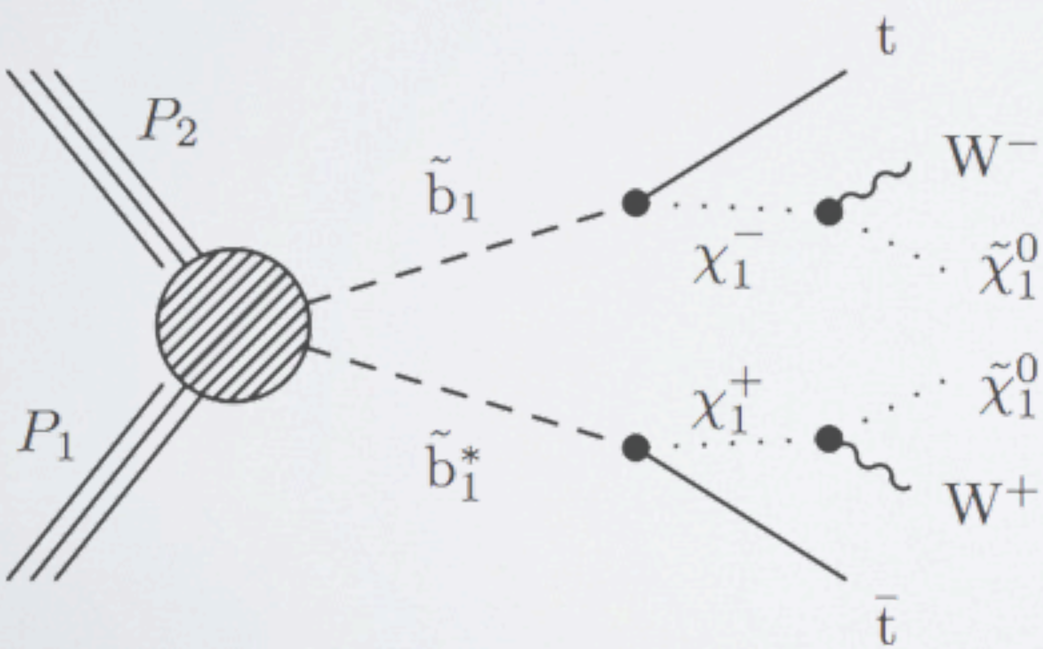
SUS-13-013

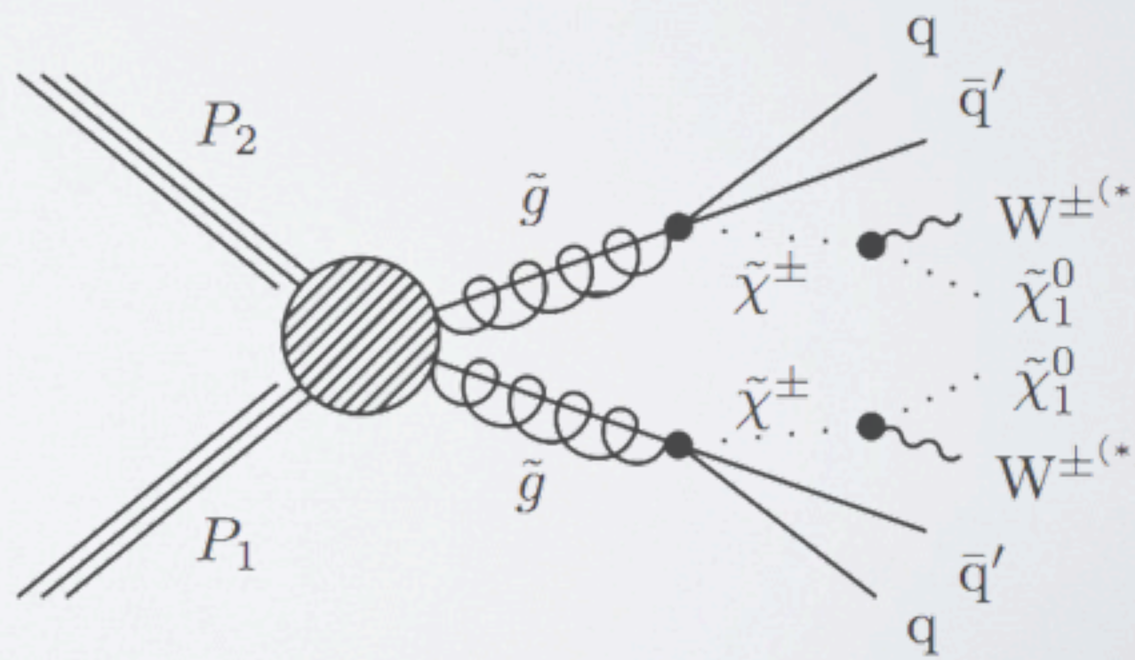
Marco - Andrea Buchmann for the CMS collaboration

SAME SIGN FINAL STATE

- Attractive signature of potential new physics
  - SM events with same-sign leptons extremely rare (→low backgrounds)
  - many models in SUSY have important contributions,

    e.g. gluino-gluino production with gluino → qq+chargino
  - adding b-tag requirement interesting in context of 3rd generation SUSY





SEARCH STRATEGY

- Select events with two isolated same-sign leptons
  - high-p_T analysis: $p_T^1>20$ GeV, $p_T^2>20$ GeV
  - low-p_T analysis: $p_T^1>10$ GeV, $p_T^2>10$ GeV
- Optimized mutually exclusive signal regions to achieve greater sensitivity to an array of different SUSY cascades

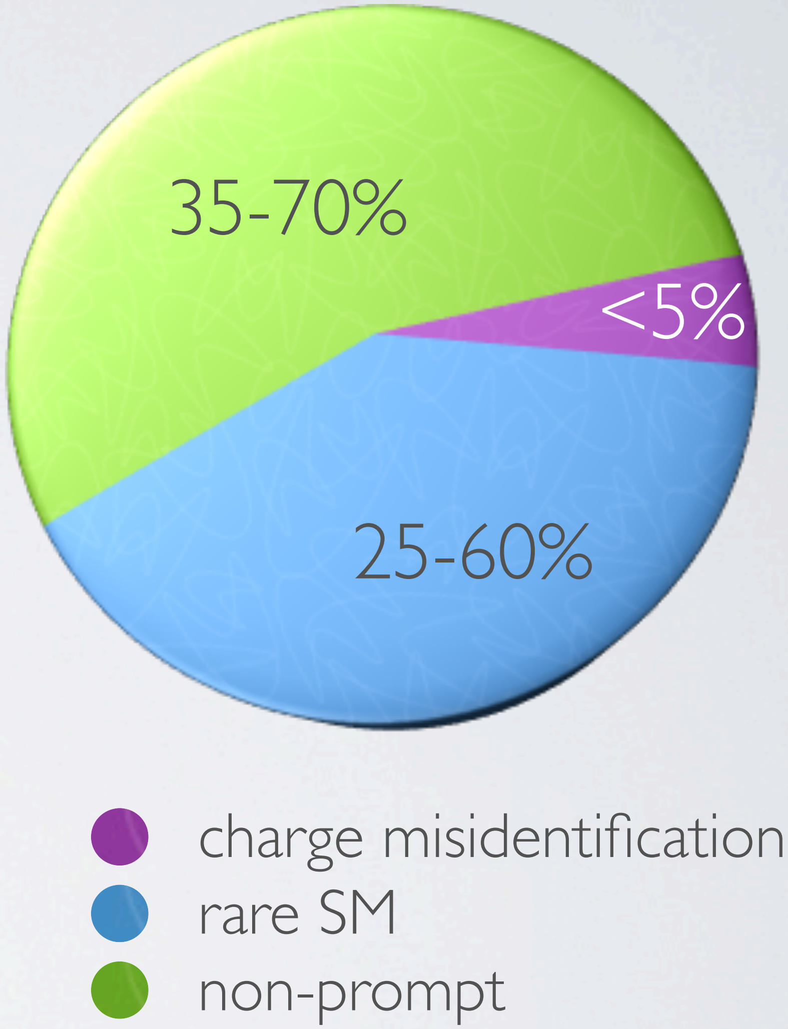
$N_{\text{b-jets}}$	E_T^{miss} (GeV)	N_{jets}	$H_T \in [200,400]$ (GeV)	$H_T > 400$ (GeV)
$=0$	50-120	2-3	SR01	SR02
		≥ 4	SR03	SR04
	>120	2-3	SR05	SR06
		≥ 4	SR07	SR08
$=1$	50-120	2-3	SR11	SR12
		≥ 4	SR13	SR14
	>120	2-3	SR15	SR16
		≥ 4	SR17	SR18
≥ 2	50-120	2-3	SR21	SR22
		≥ 4	SR23	SR24
	>120	2-3	SR25	SR26
		≥ 4	SR27	SR28

$$\vec{E}_T^{miss} = -\sum_i \vec{p}_T$$

$$H_T = \sum_{jets} |\vec{p}_T|$$

BACKGROUNDS

- Three main sources of background:
  - non-prompt leptons ("fakes"): 50% uncertainty
    - leptons not from W/Z/SUSY
    - estimate: tight-to-loose method (data-driven)
  - rare Standard Model processes: 50% uncertainty
    - mostly ttZ,TTW
    - estimated using MC
  - charge misidentification: 30% uncertainty
    - opposite sign events with one lepton charge mis-reconstruction
    - estimated by selecting opposite-sign ee and eμ events passing full selection (data-driven)
- Composition of backgrounds varies with signal region



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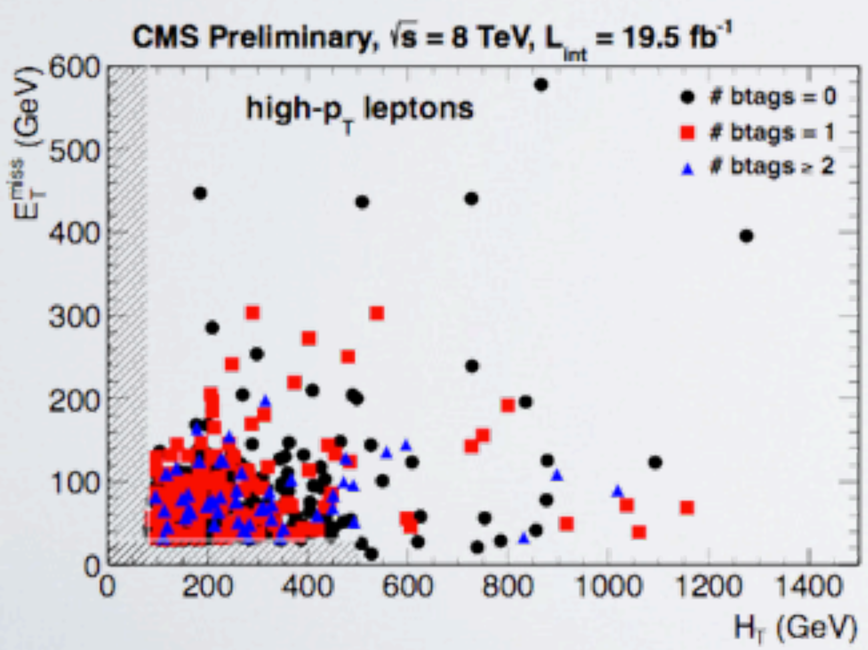
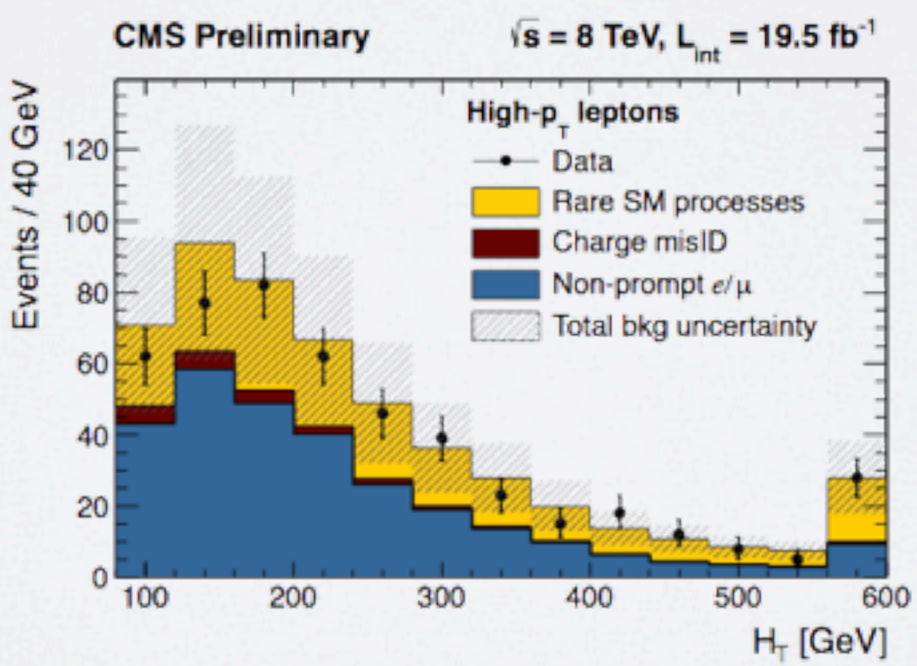
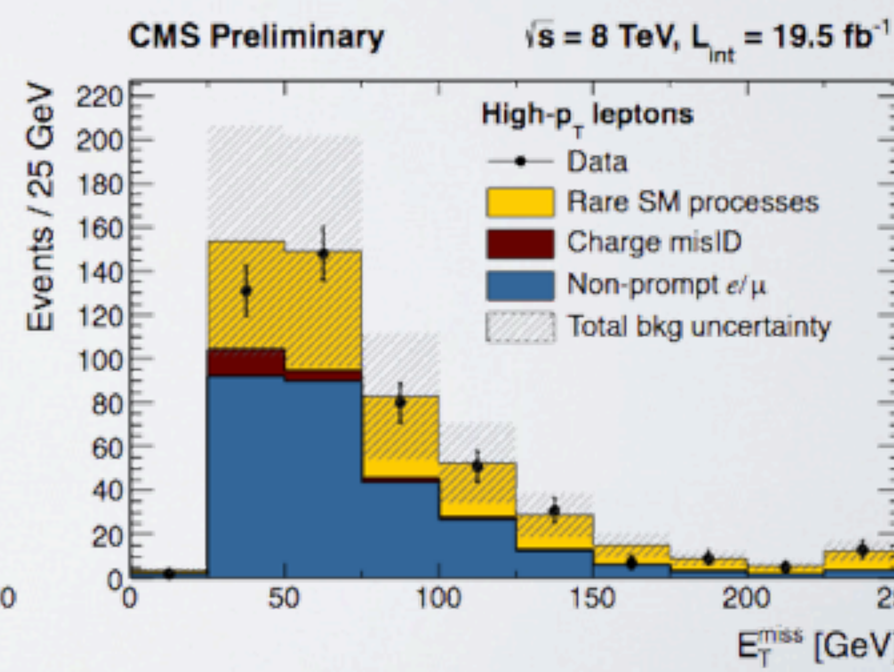
RESULTS

- Look at H_T and MET values for each event in the inclusive baseline signal region shown below (for high p_T selection)
- No significant discrepancy between observation and predictions for either low-p_T or high-p_T analysis found







INTERPRETATION

- Limits were set on a multitude of models using a statistical combination of the most sensitive, exclusive signal regions
  - considered a number of Simplified Models of Supersymmetry (SMS) which represent decay chains of new particles (which may occur in a broad range of BSM physics scenarios)
    - set upper limits on production cross-section for simplified models with gluino pair production with gluino to heavy and light flavor, sbottom-pair, and RPV
      - will only show two models here, for more see SUS-13-013
- 95% confidence level upper limits on signal yields calculated using modified frequentist CL_s method

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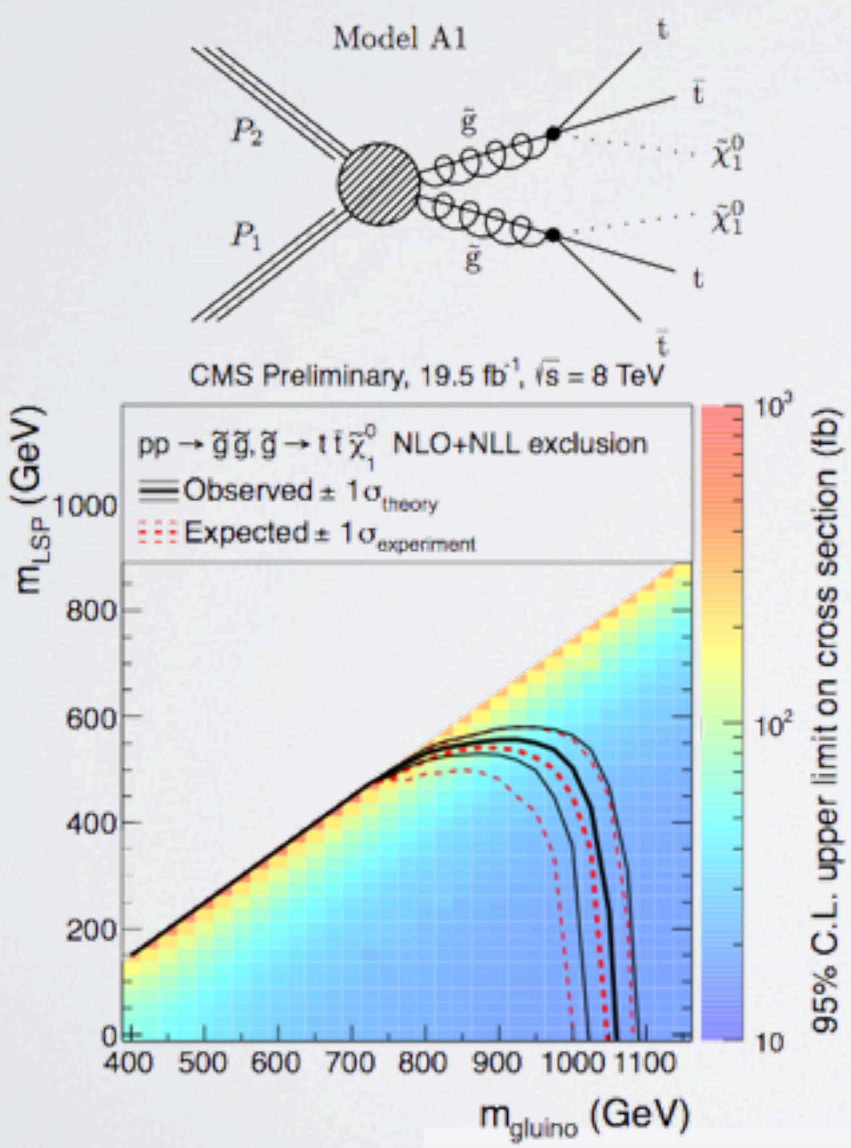
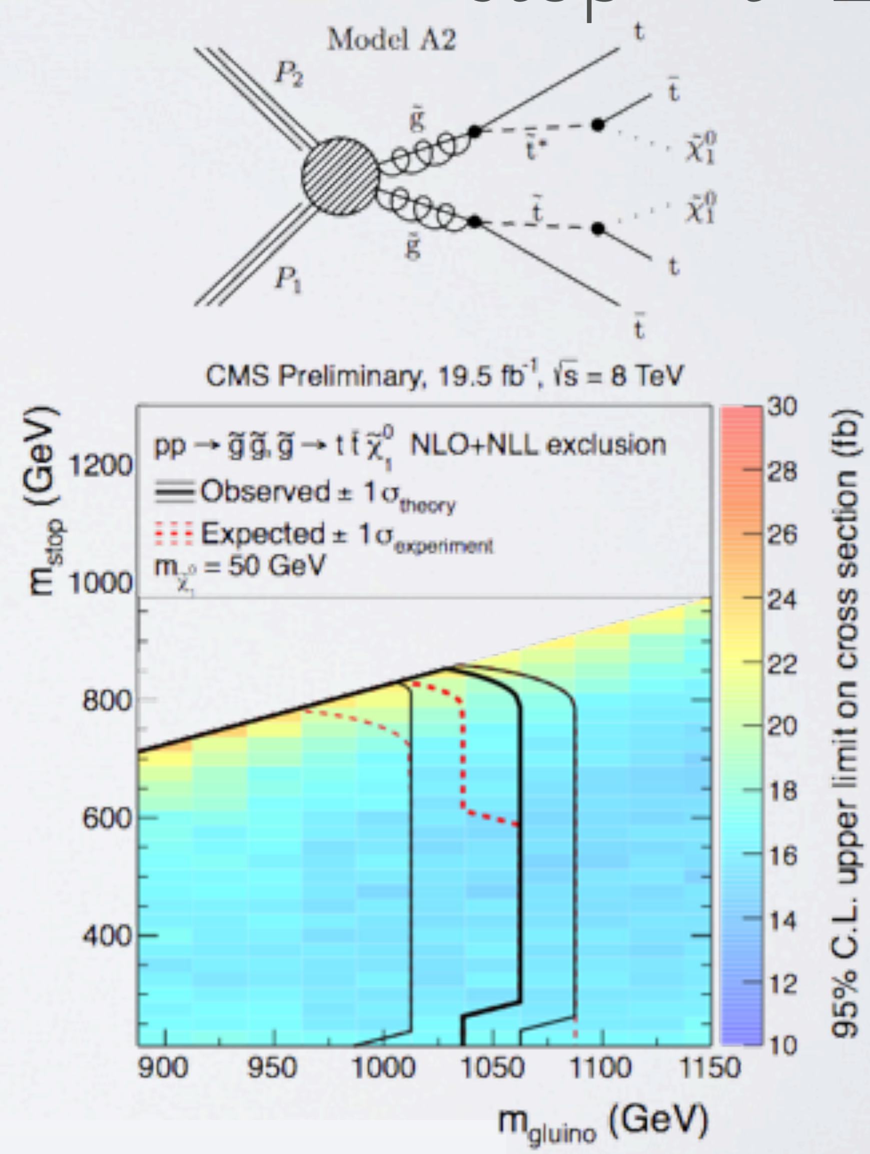
INTERPRETATION

- Consider gluino pair production

gluino → t+t+LSP



gluino → t+stop
stop → t+LSP



for many additional models see SUS-13-013

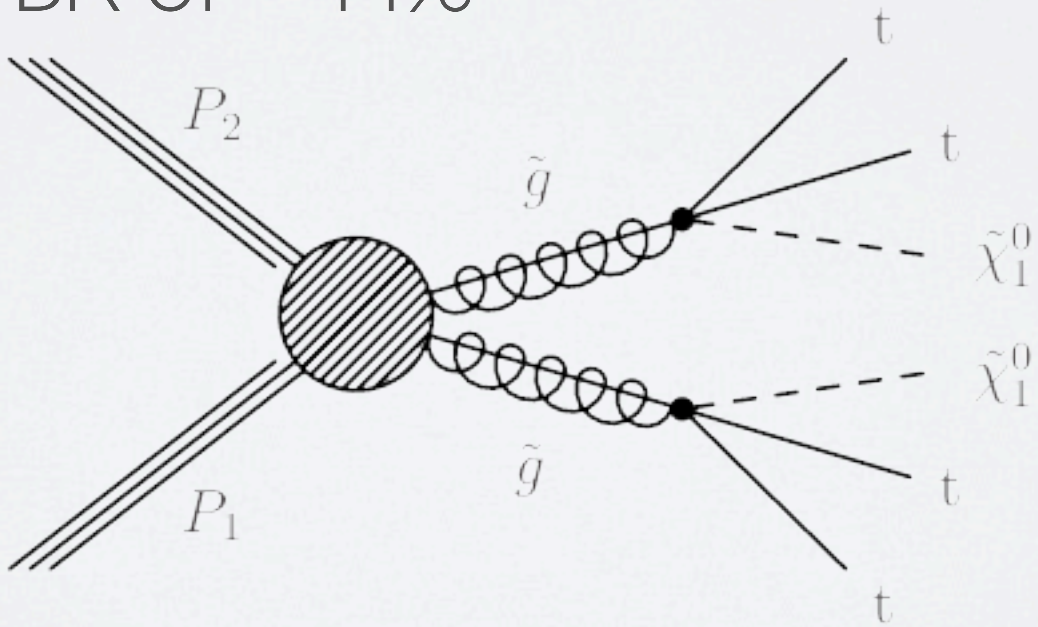
SINGLE LEPTON ANALYSIS

SUS-13-007

Marco - Andrea Buchmann for the CMS collaboration

SINGLE LEPTON FINAL STATE

- Attractive signature of potential new physics
  - Predicted by large range of BSM models
  - High branching ratio
  - Search concentrates on gluino pair production with decays to top squarks (that subsequently decay to top+LSP)
    - single lepton BR of ~44%



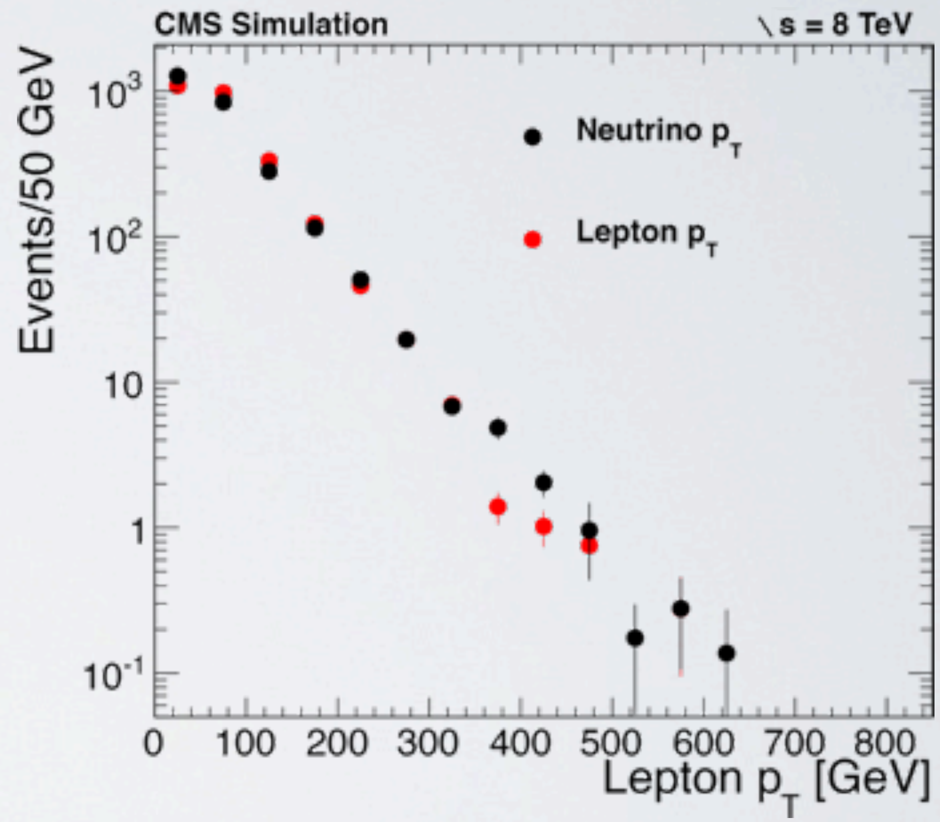
SEARCH STRATEGY

- Select events with one isolated lepton (e or μ) with p_T>20 GeV
  - veto events with additional lepton (with p_T>15 GeV)
- Require presence of at least three jets with p_T>40 GeV
- Require H_T>500 GeV (baseline selection) $H_T = \sum_{jets} |\vec{p}_T|$
- Main background: top pair production, W+Jets, single top, di-boson production and DY+jets
- Two different approaches:
  - Lepton Spectrum method
  - Delta Phi method

} Further require $N_J \geq 6$, $N_{btags} \geq 2$

LEPTON SPECTRUM METHOD (I)

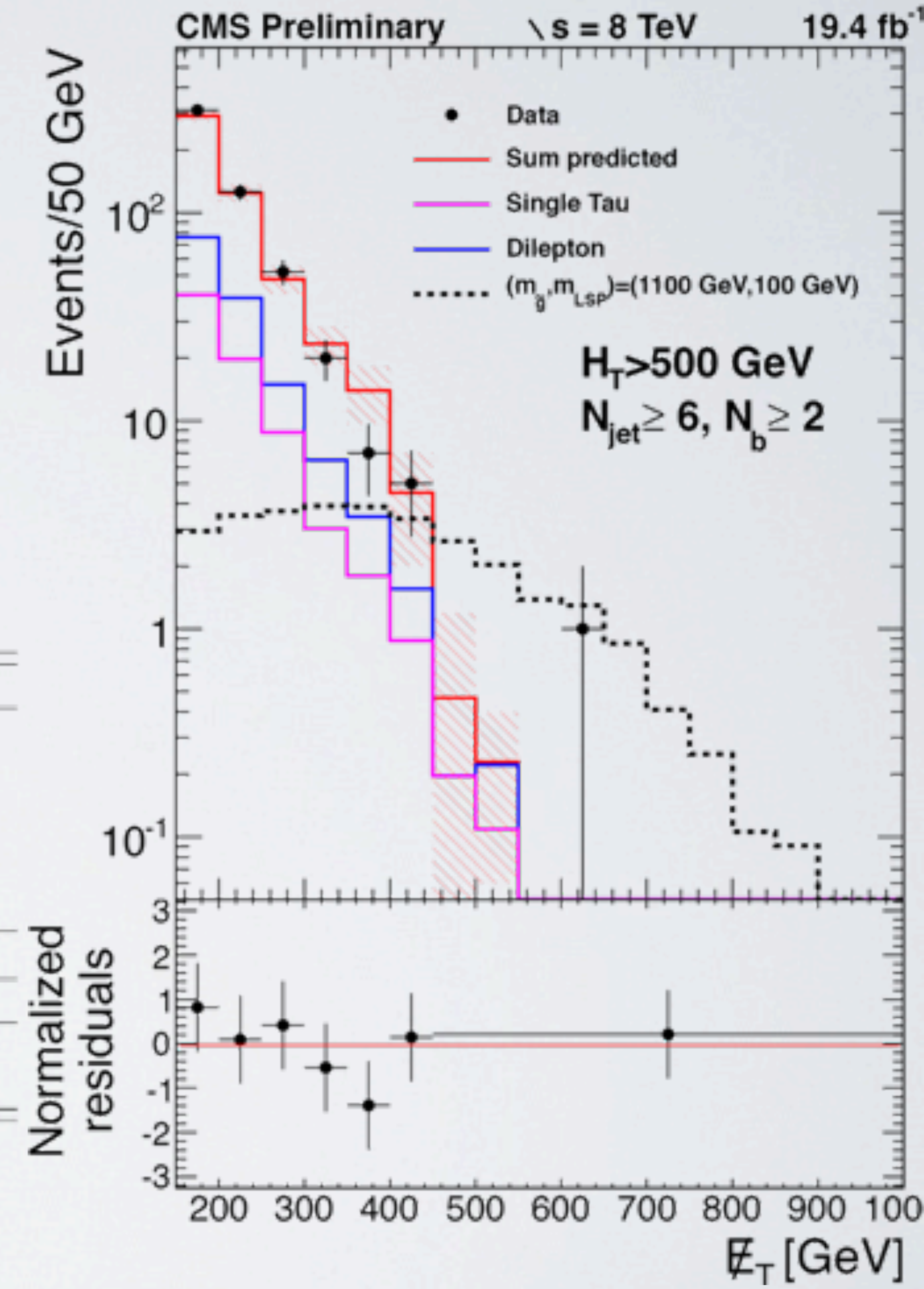
- Search in region with high MET and large H_T
- Difficult to model for backgrounds
- Dominant background: top pair production, with one $W \rightarrow l\,\nu$
  - Use similarity of neutrino and charged lepton p_T spectra in W decays
  - Correct for effects such as polarization
- sub-dominant contribution from mis-reconstructed di-lepton events (predicted from control sample)



LEPTON SPECTRUM METHOD (II)

- Results:
  - No significant excess found in any signal region
  - Example: H_T>500 GeV

$\not{E}_T$:	[150,250)	[250,350)	[350,450)	$\geq$ 450 GeV
1 ℓ	304.0±17.4±16.4	49.9±7.7±6.0	13.4±4.8±3.1	$0.3^{+1.9+0.8}_{-0.3-0.3}$
Dilepton	54.7±4.2±9.0	9.6±1.5±4.4	$2.3^{+1.3+1.0}_{-0.7-0.6}$	$0.1^{+1.8+1.8}_{-0.1-0.1}$
Single tau	60.1±2.1±5.1	11.8±0.9±3.6	2.7±0.5±1.9	0.3±0.1±0.1
Z+jets (from MC)	0.5±0.1±0.5	< 0.1	< 0.1	< 0.1
QCD multijet	1.6 ± 3.1 ± 3.1		0.0 ± 1.2 ± 1.2	
Total (predicted):	419.3±18.0±19.4	71.3±7.9±8.3	$18.4^{+5.0+3.8}_{-4.9-3.7}$	$0.7^{+2.6+2.0}_{-0.3-0.3}$
Data (observed), **total** (μ, e):	**437** (237, 200)	**72** (38, 34)	**12** (7, 5)	**1** (0, 1)
SMS ($m_{\tilde{g}}$ = 1150 GeV, m_{LSP} = 500 GeV)	5.1±0.2	5.6±0.2	3.7±0.2	3.0±0.2
SMS ($m_{\tilde{g}}$ = 1100 GeV, m_{LSP} = 100 GeV)	6.5±0.3	7.6±0.3	7.3±0.3	9.1±0.3



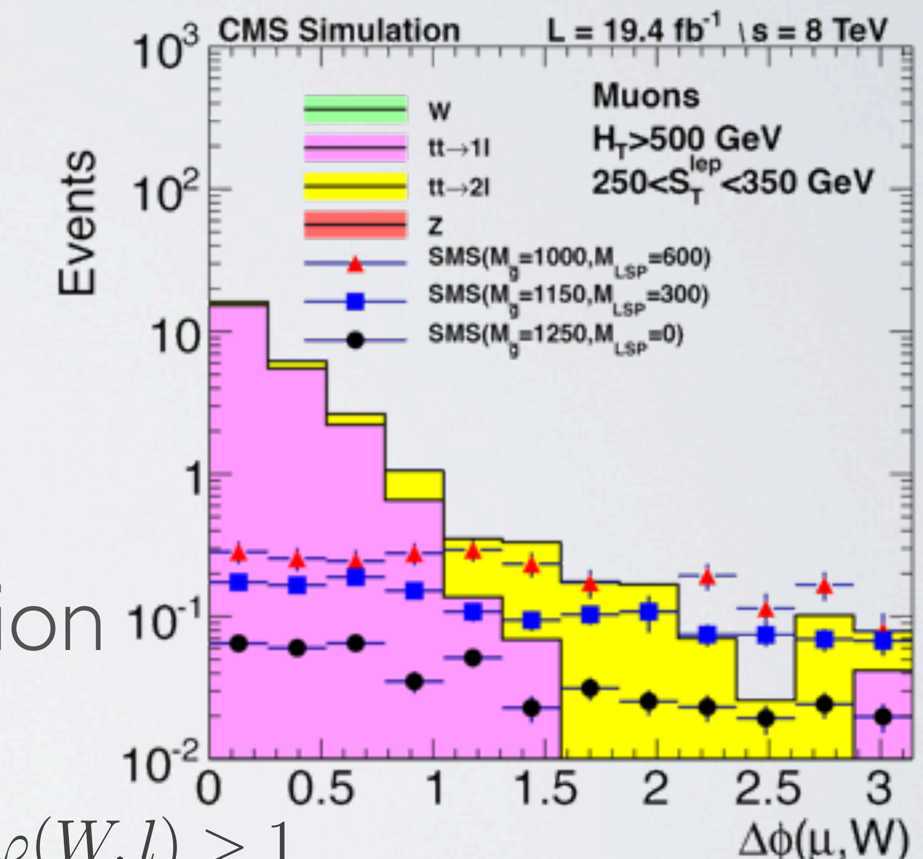
DELTA PHI METHOD (I)

- Consider angle between lepton and W momentum Δϕ(W,l) and leptonic mass scale $S_T^{lep} = \sqrt{p_T(W)^2 + M_T(W)^2}$
- Background dominated by top pair production with W →lν
  - Δϕ(W,l) has maximum value
- No such maximum in SUSY
- Use Δϕ(W,l) to define signal & control region
  - use transfer factor:

$$R_{CS} = \frac{N_{signal}}{N_{control}} = \frac{\text{Number of events with } \Delta\varphi(W,l) > 1}{\text{Number of events with } \Delta\varphi(W,l) < 1}$$

  - to get estimate:

$$\underbrace{N_{SM}^{pred}(\Delta\varphi(W,l) > 1)}_{\text{number of events in signal region}} = R_{CS} \cdot \underbrace{N_{data}(\Delta\varphi(W,l) < 1)}_{\text{number of events in control region}}$$



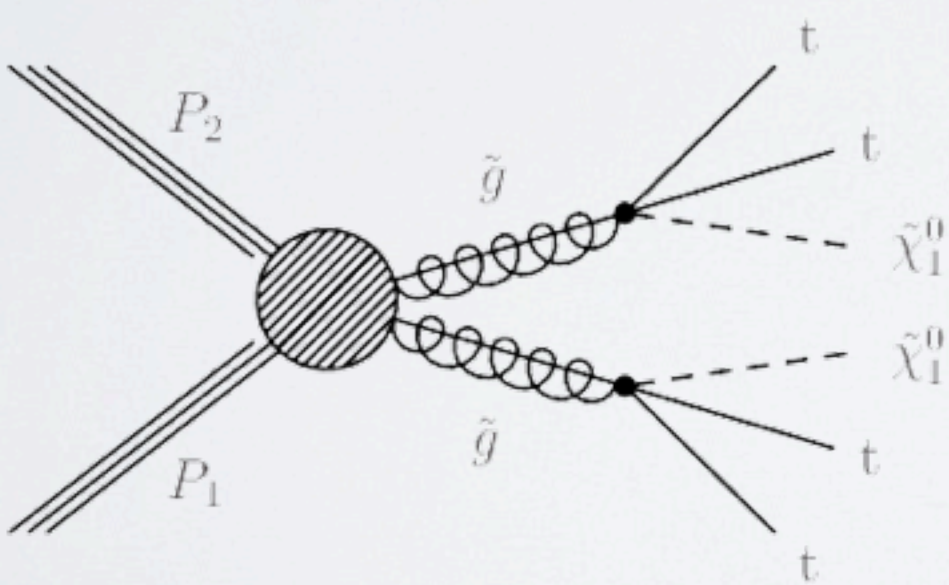
DELTA PHI METHOD (II)

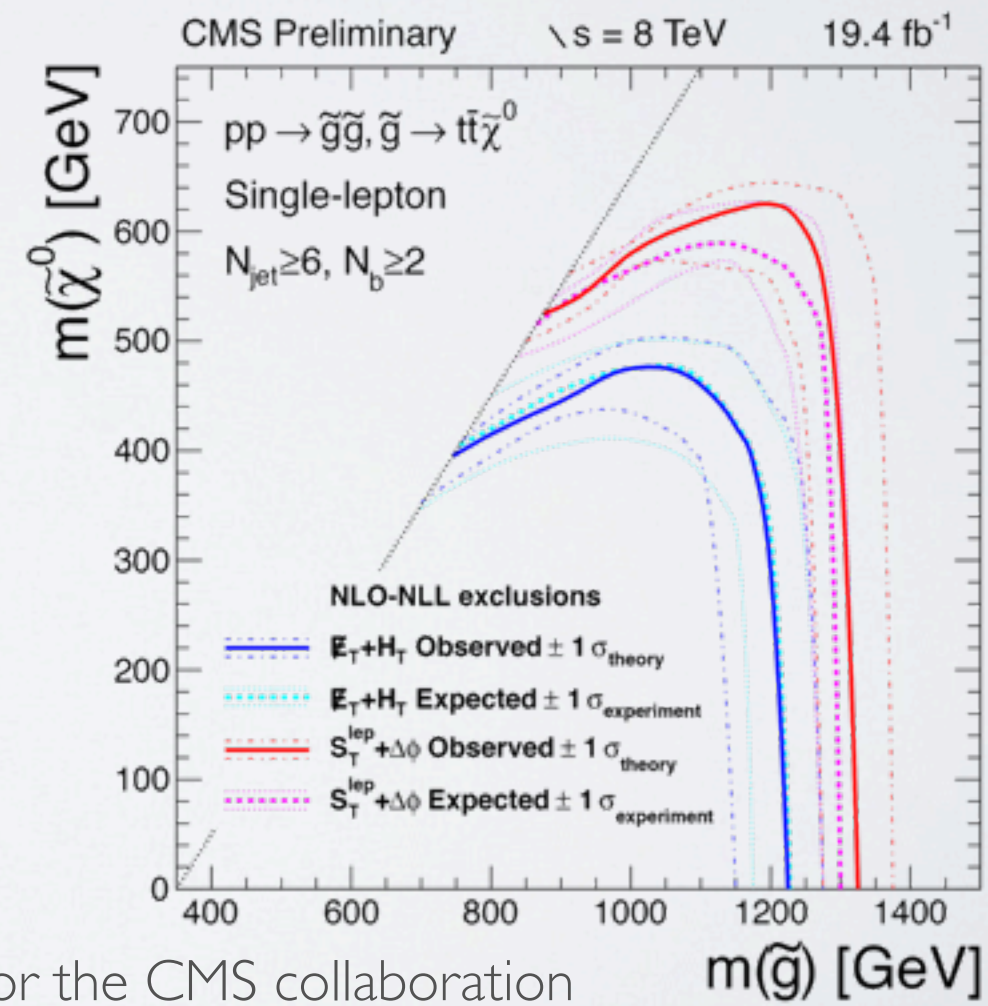
- Results:
  - No significant excess found

		S_T^{lep} [GeV]	control reg. data	prediction	observation
N_b=2	Muons	[250,350]	632	41.94± 5.63	59
		[350,450]	188	8.51± 2.39	11
		> 450	71	2.46± 1.32	1
	Electr.	[250,350]	548	34.23±5.37	30
		[350,450]	174	5.11±1.85	8
		>450	61	5.57±2.14	1
N_b ≥3	Muons	[250,350]	59	3.88±0.81	5
		[350,450]	25	1.09±0.44	0
		> 450	7	0.26±0.21	0
	Electr.	[250,350]	70	3.91±0.92	2
		[350,450]	12	0.32±0.16	2
		>450	4	0.32±0.24	0

SINGLE LEPTON INTERPRETATION

- Two approaches probe complementary kinematic aspects
- Set limits for both methods for a simplified model with gluino pair production

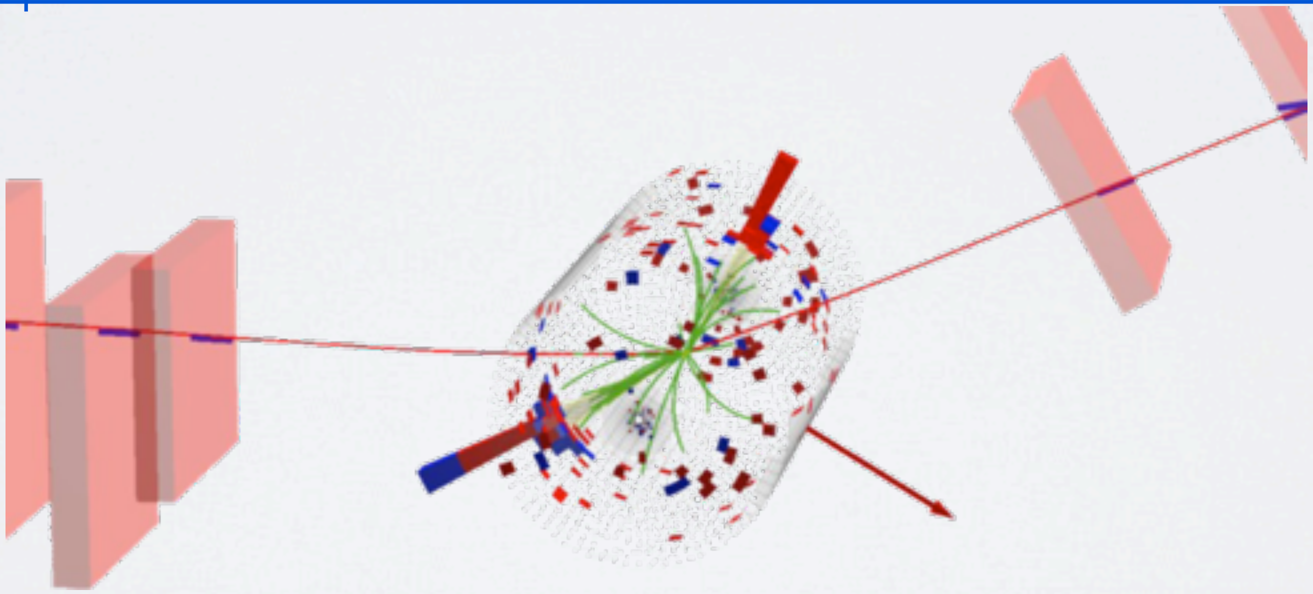




CONCLUSIONS

CONCLUSIONS

- Presented two CMS searches with new results containing leptons
- No significant excess has been found, interpreted results in the context of Simplified Models of Supersymmetry
- Excluded gluino mass up to 1.3 TeV for LSP mass up to about 550 GeV (SL), and probed gluinos with masses up to ~1050 GeV and top squarks up to ~800 GeV
- More new results coming, stay tuned!
- For more, visit https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS



Ref:
"Search for new physics in events with same-sign dileptons and jets" CMS PAS SUS-13-013
"Search for supersymmetry in events with a single lepton, multiple jets and b-tags", CMS PAS SUS-13-007

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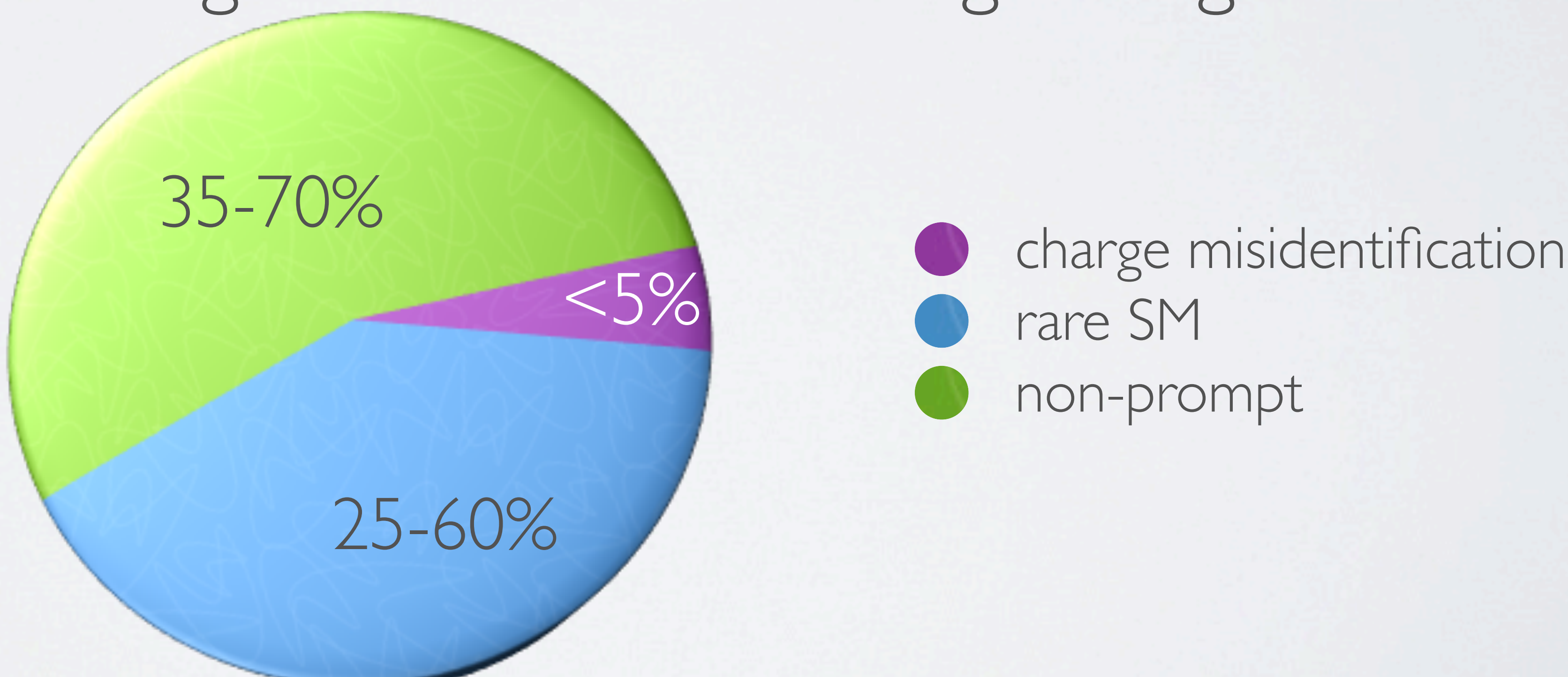
SS CMS

BACKUP

BACKGROUNDS

- Three main sources of background:
  - non-prompt leptons ("fakes")
  - irreducible, rare Standard Model processes
  - charge misidentification
- Composition of backgrounds varies with signal region



BACKGROUND PREDICTION

- non-prompt background:
  - leptons not coming from W/Z/SUSY
  - sources: real leptons from heavy flavor jets (top pair production) or mis-identified jets (W+Jets,DY+Jets, QCD, ...)
  - estimated using tight-to-loose method
    - based on "fake probability" measured in background enriched region with looser selection and applied in signal region
    - systematic uncertainty: 50%

BACKGROUND PREDICTION

- charge mis-identification:
  - events with opposite-sign isolated leptons where charge of one of the leptons is mis-reconstructed
    - relevant only for electrons, negligible for muons (since lever is much larger)
  - Estimated by selecting opposite-sign ee or eμ events passing full kinematic selection, weighted by p_T and η dependent probability of electron charge mis-assignment
  - systematic uncertainty: 30%

BACKGROUND PREDICTION

- rare SM:
  - mostly from ttW, ttZ and diboson production
  - Estimated from Monte Carlo simulation
  - systematic uncertainty: 50%
- total background (for each signal region)
  - sum of yields of all backgrounds
  - individual uncertainties treated as uncorrelated
  - note that this analysis has high sensitivity due to the extremely low background rates

SAME SIGN: KINEMATIC REQUIREMENTS

Table 1: Kinematic requirements on leptons and jets that are used to define the low-p_T (high-p_T) analysis.

	$p_T(GeV)$	$\|\eta\|$
electrons	$> 10(20)$	< 2.4 and $\notin [1.442, 1.566]$
muons	$> 10(20)$	< 2.4
jets	> 40	< 2.4
b-tagged jets	> 40	< 2.4

SAME SIGN: BASELINE SIGNAL REGIONS

Table 2: Definition of the baseline signal regions for the three different requirements on the number of b-tagged jets ($N_{\mathrm{b-jets}}$). N_{jets} refers to the number of jets in the event. The same naming scheme is used for both the high- and low-p_{T} analyses which differ only in a looser requirement on H_{T} (in parentheses) for the high-p_{T} analysis.

H_{T} (GeV)	$E_{\mathrm{T}}^{\mathrm{miss}}$ (GeV)	N_{jets}	$N_{\mathrm{b-jets}}$	SR
> 250 (80)	> 30 if $H_{\mathrm{T}} < 500$ else > 0	≥ 2	$= 0$	BSR0
> 250 (80)	> 30 if $H_{\mathrm{T}} < 500$ else > 0	≥ 2	$= 1$	BSR1
> 250 (80)	> 30 if $H_{\mathrm{T}} < 500$ else > 0	≥ 2	≥ 2	BSR2

SAME SIGN: SIGNAL REGIONS

Table 3: Definition of the signal regions for the high-p_T analysis. The low-p_T analysis employs a tighter requirement $H_T > 250$ GeV and uses the same numbering scheme where the first number in the name represents the requirement on the number of b-tagged jets for that search region, i.e. SR01, SR11, SR21 correspond to SRs with N_{b-jets} 0, 1 ≥ 2 respectively.

N_{b-jets}	E_T^{miss} (GeV)	N_{jets}	$H_T \in [200, 400]$ (GeV)	$H_T > 400$ (GeV)
$= 0$	50-120	2-3	SR01	SR02
		≥ 4	SR03	SR04
	> 120	2-3	SR05	SR06
		≥ 4	SR07	SR08
$= 1$	50-120	2-3	SR11	SR12
		≥ 4	SR13	SR14
	> 120	2-3	SR15	SR16
		≥ 4	SR17	SR18
≥ 2	50-120	2-3	SR21	SR22
		≥ 4	SR23	SR24
	> 120	2-3	SR25	SR26
		≥ 4	SR27	SR28

SAME SIGN: SIGNAL REGIONS

Table 4: Signal regions (SR) that are used for the search of same-sign top production and RPV SUSY processes.

N_{jets}	N_{b-jets}	E_T^{miss} (GeV)	H_T (GeV)	charge	SR
≥ 2	≥ 0	> 0	> 500	++/−−	RPV0
≥ 2	≥ 2	> 0	> 500	++/−−	RPV2
≥ 2	$= 1$	> 30	> 80	++/−−	SStop1
≥ 2	$= 1$	> 30	> 80	++ only	SStop1++
≥ 2	≥ 2	> 30	> 80	++/−−	SStop2
≥ 2	≥ 2	> 30	> 80	++ only	SStop2++

SAME SIGN: SYSTEMATIC UNCERT.

Table 6: Summary of representative systematic uncertainties on the selection efficiency for the considered signal models.

Source	%
Luminosity	4.4
Modeling of lepton selection (ID and isolation)	10
Jet energy scale	1–10
Jet energy resolution	0–3
b-jet identification	2–10
Trigger scaling	6
ISR modeling	3–15
Pileup modeling	5
Total	14–23

SAME SIGN: RESULTS

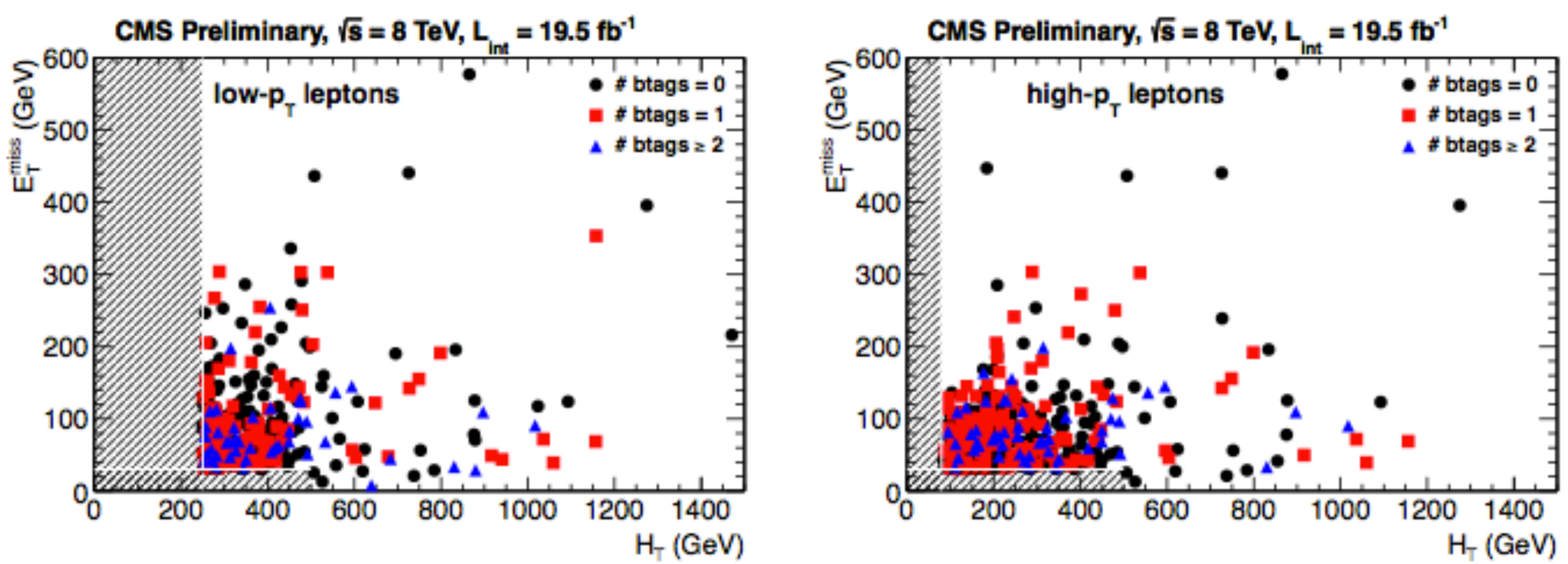
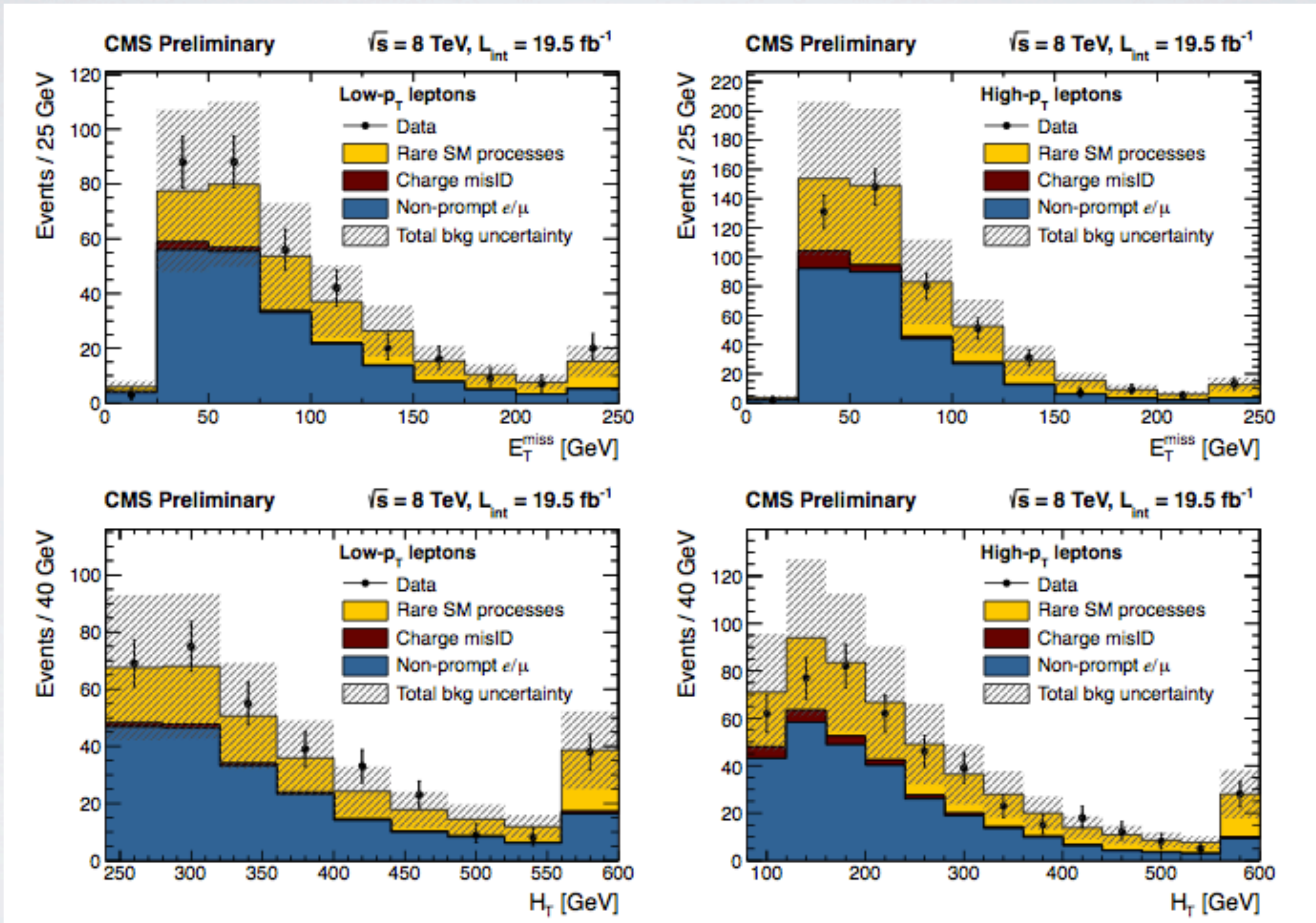


Figure 1: Distributions of E_T^{miss} versus H_T in the baseline signal regions BSR0, BSR1 and BSR2 for the low-p_T (left) and the high-p_T (right) analyses. The regions indicated with the hatched area are not included in the analysis.

SAME SIGN: RESULTS



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SAME SIGN: RESULTS

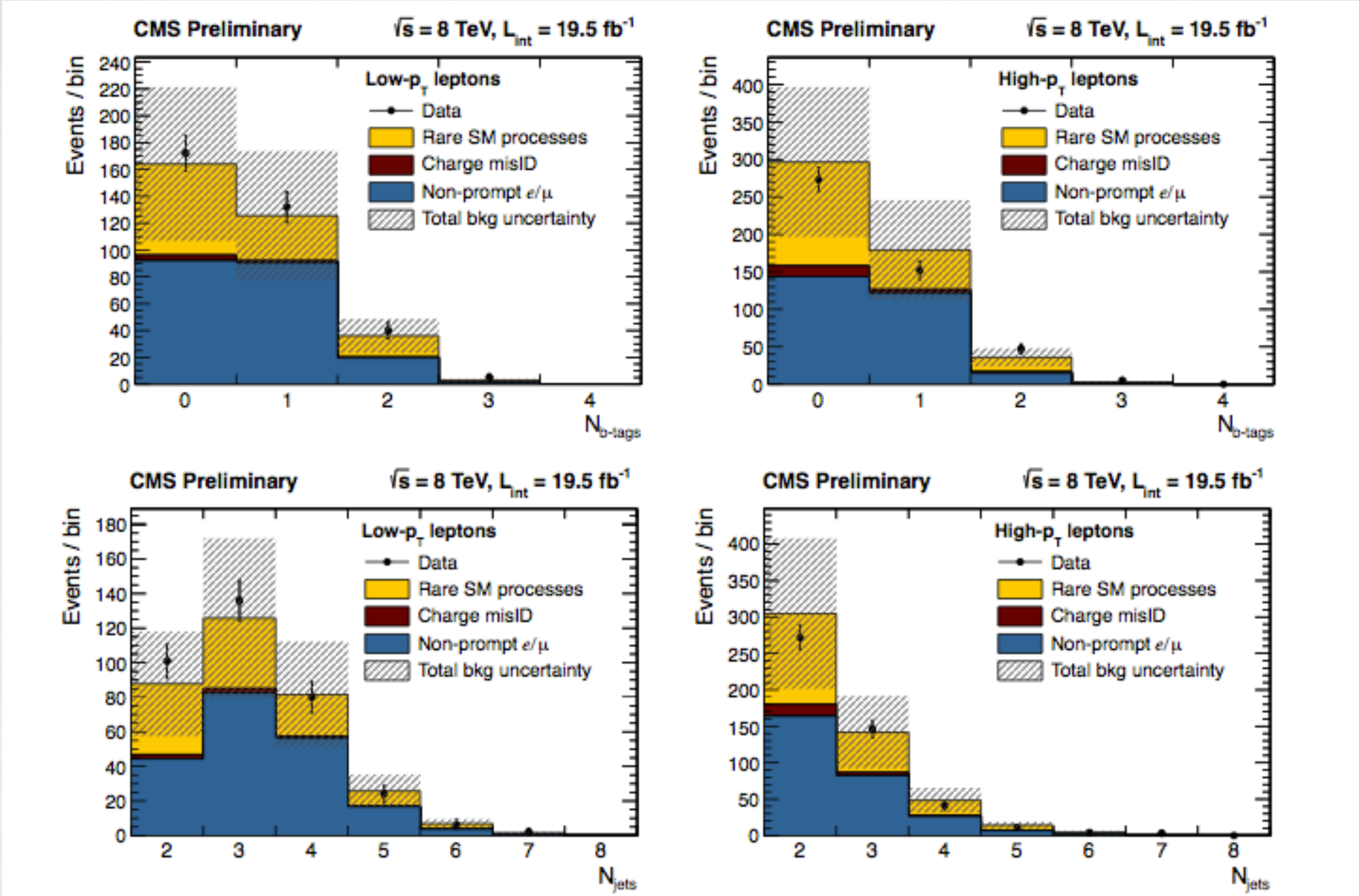

Figure 2: Distributions of $E_{\mathrm{T}}^{\mathrm{miss}}$, H_{T}, number of b-tagged jets, and number of jets for the events in the low-p_{T} (high-p_{T}) baseline region with no $N_{\mathrm{b-jets}}$ requirement (SR0) are shown on the left (right). Also shown as a histogram is the result of the background prediction. The shaded region in the histograms represents the total uncertainty in the background prediction.

SAME SIGN: RESULTS

Table 7: Predicted and observed yields for the low-, and high-p_T signal regions.

SR	low-p_T Expected	low-p_T Observed	high-p_T Expected	high-p_T Observed
1	44 ± 16	50	51 ± 18	48
2	12 ± 4	17	9.0 ± 3.5	11
3	12 ± 5	13	8.0 ± 3.1	5
4	9.1 ± 3.4	4	5.6 ± 2.1	2
5	21 ± 8	22	20 ± 7	12
6	13 ± 5	18	9 ± 4	11
7	3.5 ± 1.4	2	2.4 ± 1.0	1
8	5.8 ± 2.1	4	3.6 ± 1.5	3
11	32 ± 13	40	36 ± 14	29
12	6.0 ± 2.2	5	3.8 ± 1.4	5
13	17 ± 7	15	10 ± 4	6
14	10 ± 4	6	5.9 ± 2.2	2
15	13 ± 5	9	11 ± 4	11
16	5.5 ± 2.0	5	3.9 ± 1.5	2
17	4.2 ± 1.6	3	2.8 ± 1.1	3
18	6.8 ± 2.5	11	4.0 ± 1.5	7
21	7.6 ± 2.8	10	7.1 ± 2.5	12
22	1.5 ± 0.7	1	1.0 ± 0.5	1
23	7.1 ± 2.7	6	3.8 ± 1.4	3
24	4.4 ± 1.7	11	2.8 ± 1.2	7
25	2.8 ± 1.1	1	2.9 ± 1.1	4
26	1.3 ± 0.6	2	0.8 ± 0.5	1
27	1.8 ± 0.8	0	1.2 ± 0.6	0
28	3.4 ± 1.3	3	2.2 ± 1.0	2

SAME SIGN: RESULTS

Table 8: Predicted and observed yields in the signal regions designed for same-sign top-pair production and RPV SUSY models.

SR	Expected	Observed
RPV0	38 ± 14	35
RPV2	5.3 ± 2.1	5
SStop1	160 ± 59	152
SStop1++	90 ± 32	92
SStop2	40 ± 13	52
SStop2++	22 ± 8	25

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SAME SIGN: RESULTS

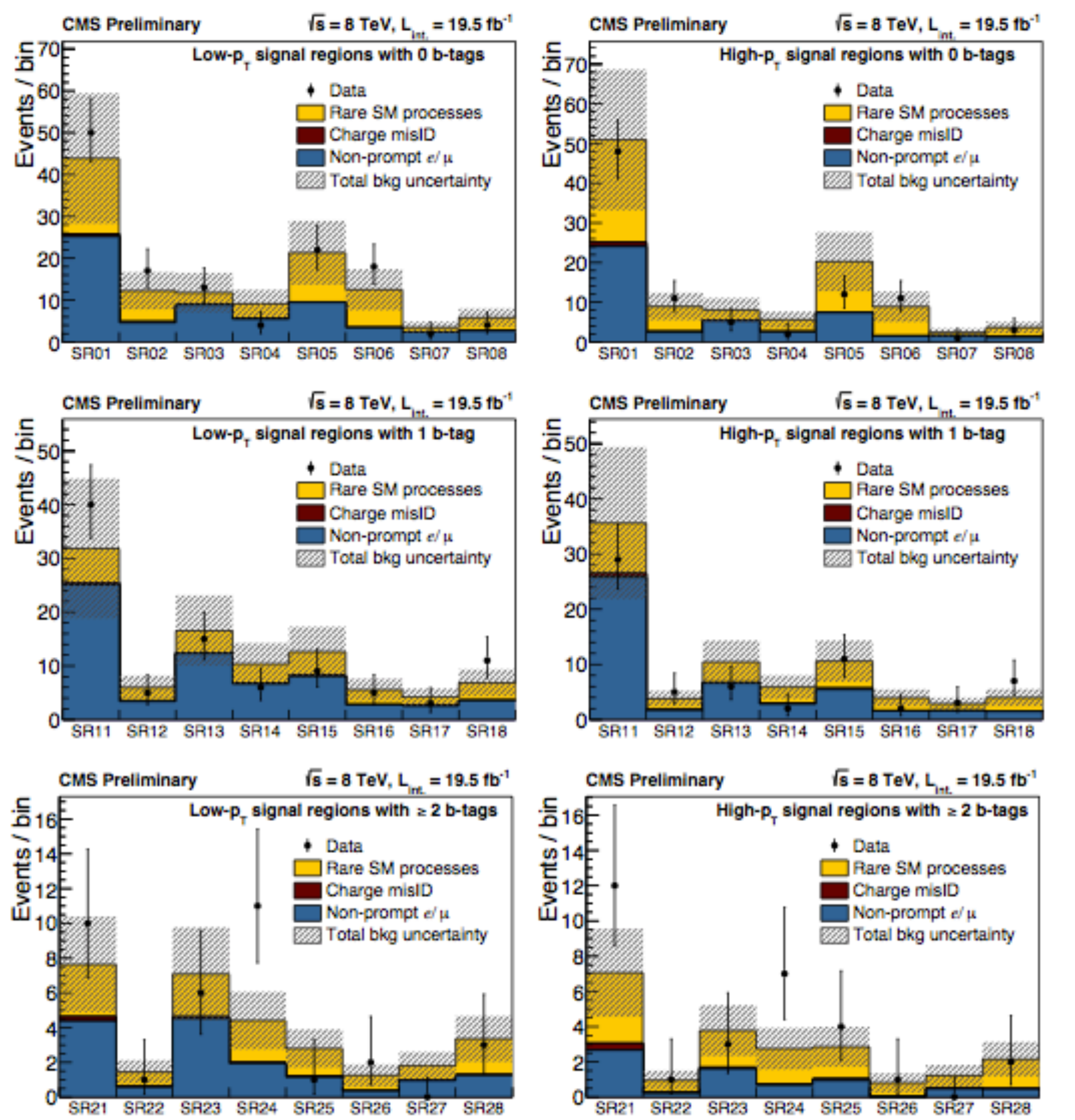


Figure 3: Summary plots showing the predicted background from each source and observed event yields as a function of the SRs in the low (high)-p_T analysis on left (right).

SAME SIGN: INTERPRETATION

Table 9: Summary of the signal regions used for limit setting in each new physics model.

Model	Model parameter	Analysis	Signal Regions used
A1		high-p_T	21–28
A2	$m_{\tilde{\chi}^0} = 50$ GeV	high-p_T	21–28
B1	$m_{\tilde{\chi}^0} = 50$ GeV	high-p_T	11–18, 21–28
B1	$x = m_{\tilde{\chi}^0}/m_{\tilde{\chi}_1^\pm} = 0.5$	high-p_T	11–18, 21–28
B1	$x = m_{\tilde{\chi}^0}/m_{\tilde{\chi}_1^\pm} = 0.8$	low-p_T	11–18, 21–28
B2	$m_{\tilde{\chi}^0} = 50$ GeV, $m_{\tilde{\chi}_1^\pm} = 150$ GeV	high-p_T	21–28
B2	$m_{\tilde{\chi}^0} = 50$ GeV, $m_{\tilde{\chi}_1^\pm} = 300$ GeV	high-p_T	21–28
C1	$x = 0.5$	high-p_T	01–08
C1	$x = 0.8$	low-p_T	01–08
RPV		high-p_T	RPV2
$pp \to tt + \bar{t}\bar{t}$		high-p_T	SStop1, SStop2
$pp \to tt$		high-p_T	SStop1++, SStop2++
$pp \to tt\bar{t}\bar{t}$		high-p_T	21–28

SAME SIGN: INTERPRETATION

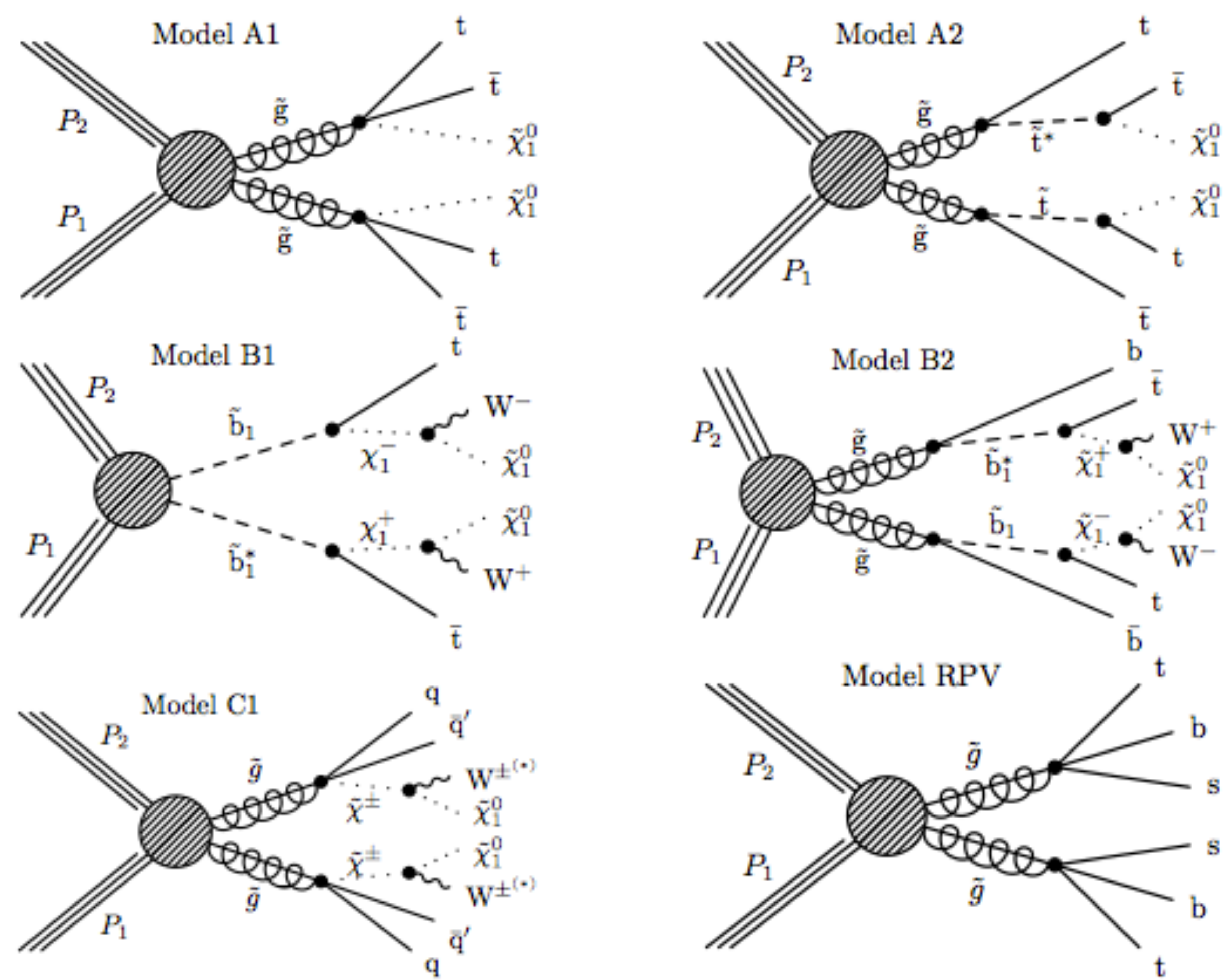
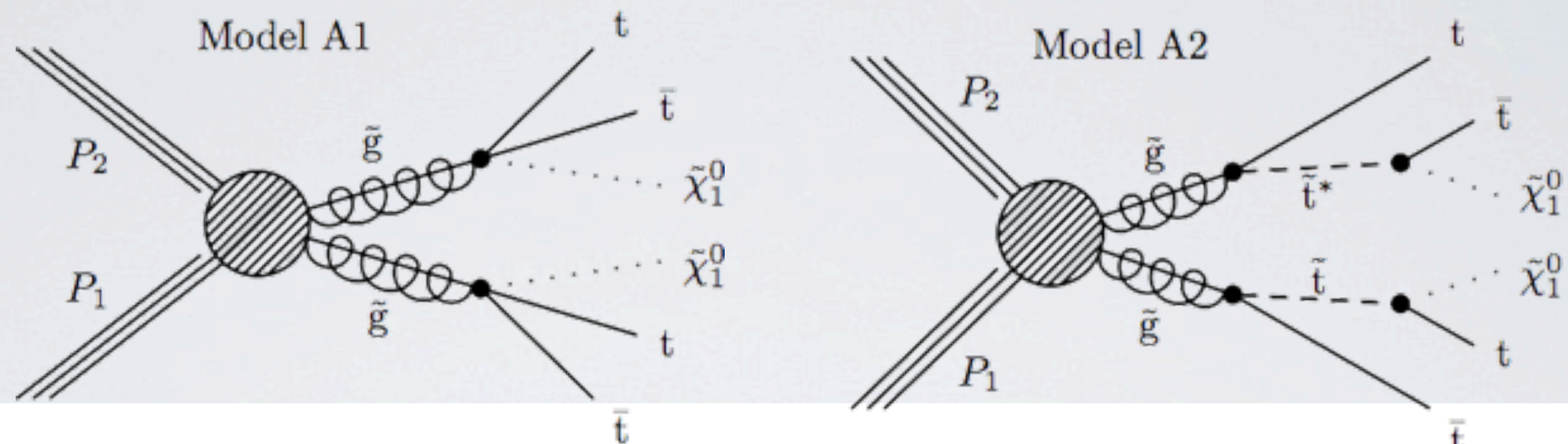


Figure 4: Diagrams for the six SUSY models considered (A1, A2, B1, B2 and C1, RPV).

SAME SIGN: INTERPRETATION



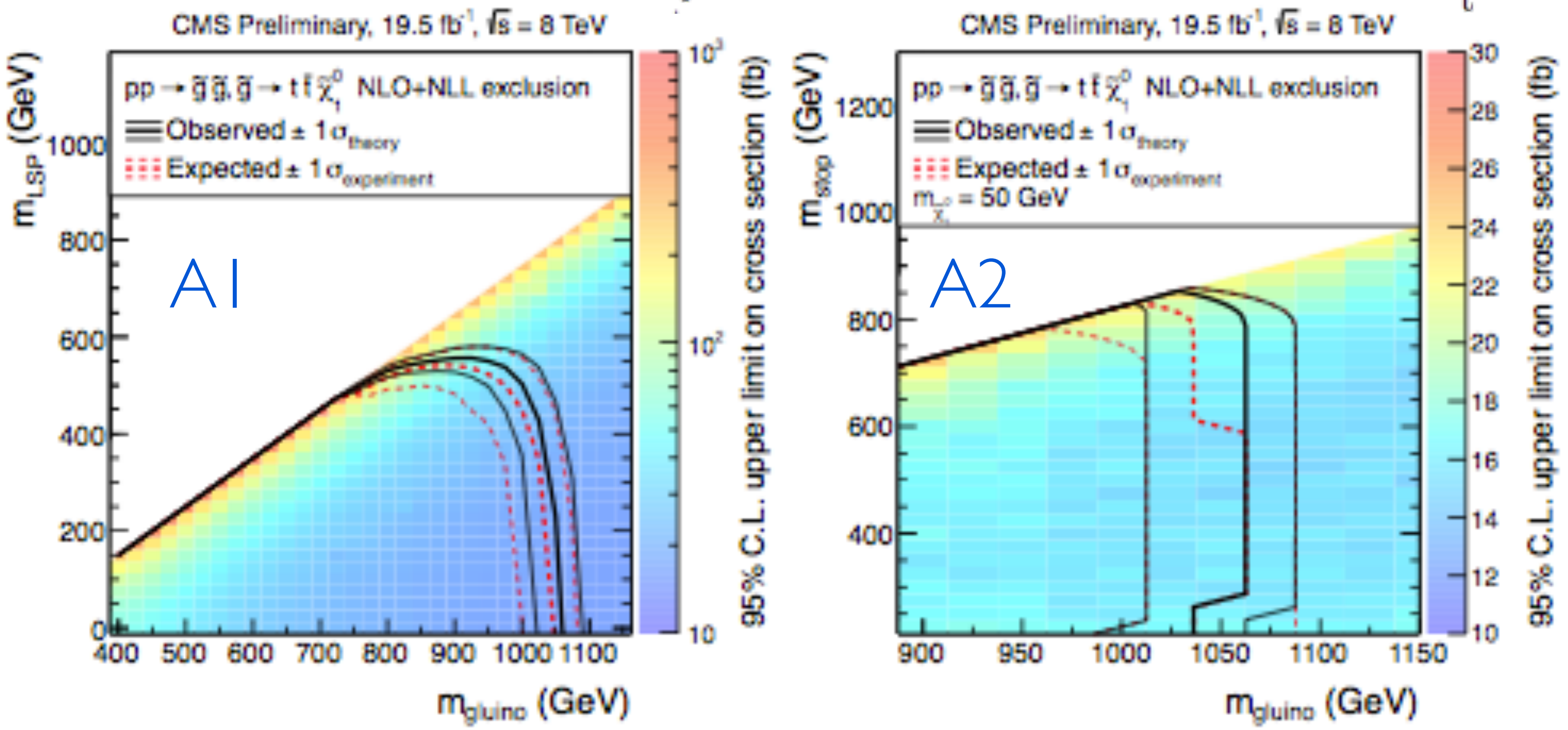


Figure 5: Exclusion regions at 95% CL in the planes of $m(\tilde{\chi}_1^0)$ *vs.* $m(\tilde{g})$ (model A1) and $m(\tilde{t}_1)$ *vs.* $m(\tilde{g})$ (model A2). The excluded regions are those within the kinematic boundaries and to the left of the curves. The effects of the theoretical uncertainties in the next-to-leading-order plus next-to-leading-log calculations of the production cross sections [38] are indicated by the black-thin curves; the expected limits and their ± 1 standard-deviation variations are also shown in dashed red curves.

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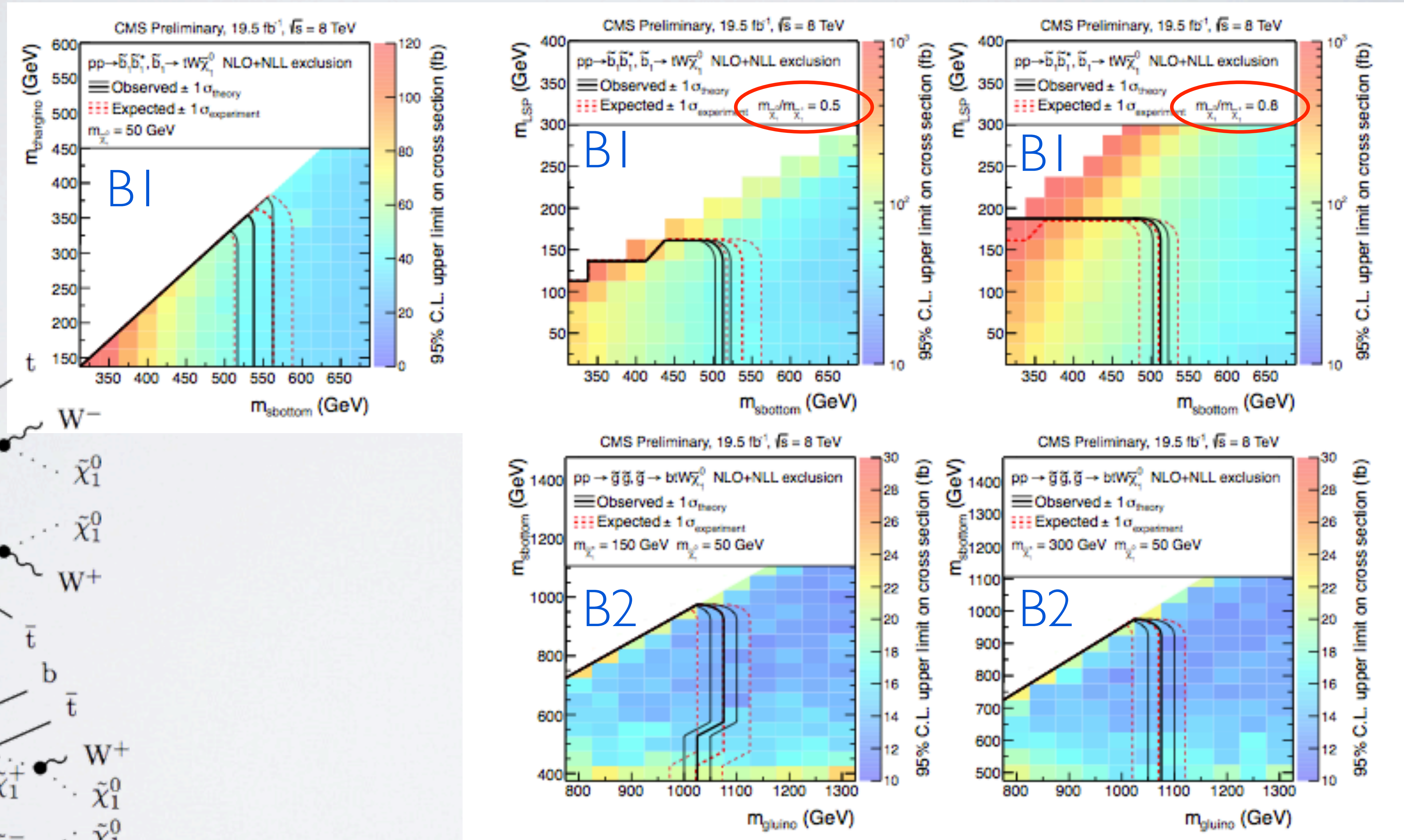
SAME SIGN: INTERPRETATION



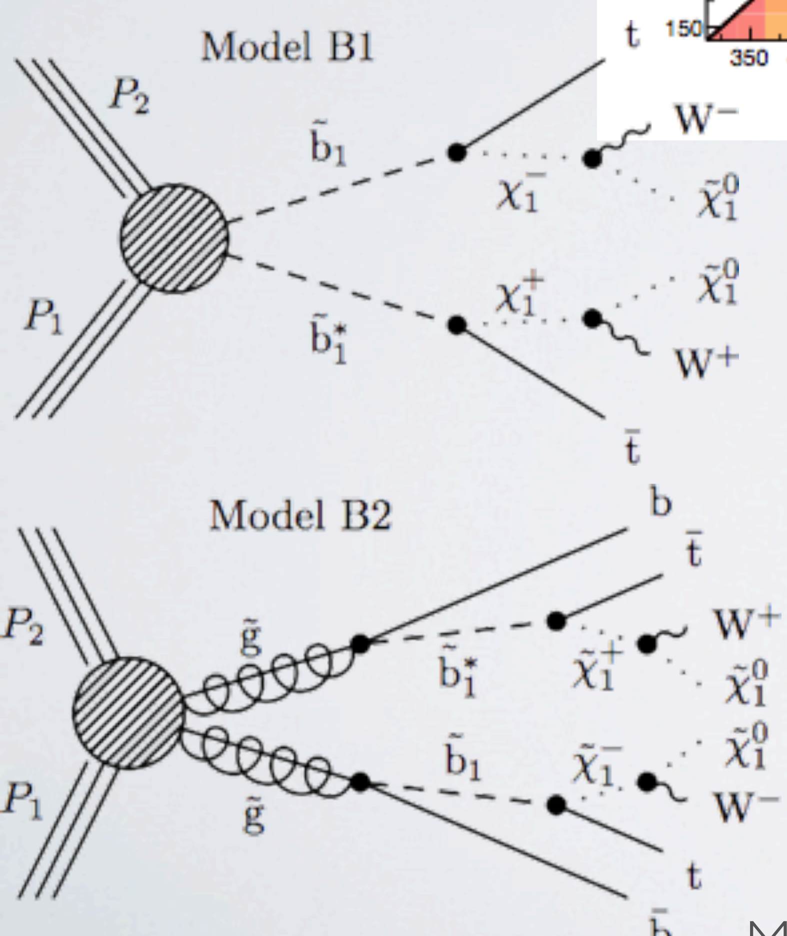
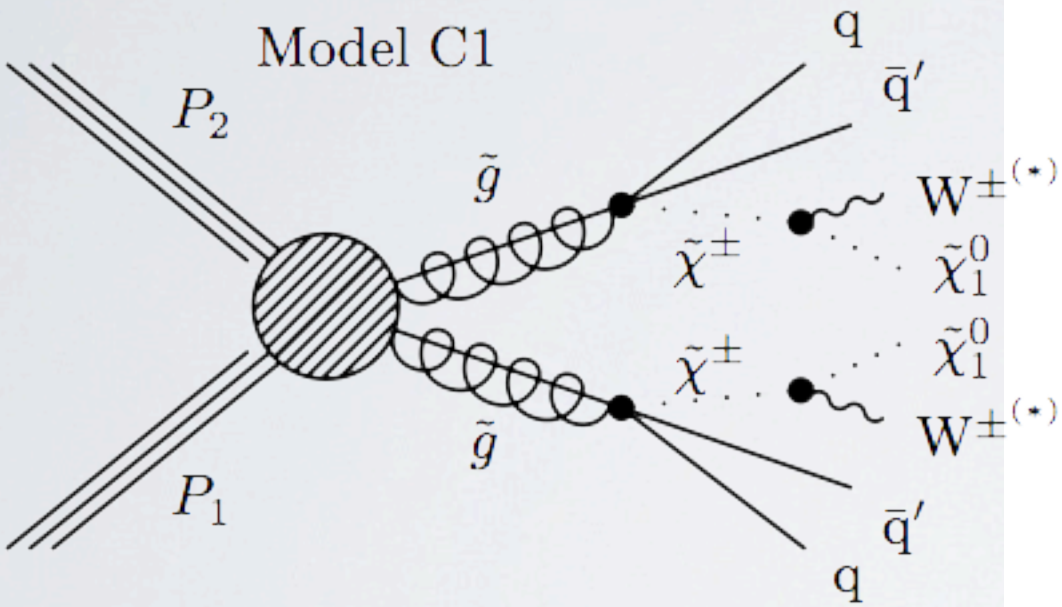


Figure 6: Exclusion regions at 95% CL in the planes of $m(\tilde{\chi}_1^{\pm})$ vs. $m(\tilde{b}_1)$ and $m(\tilde{\chi}_1^0)$ vs. $m(\tilde{b}_1)$ (model B1) and $m(\tilde{b}_1)$ vs. $m(\tilde{g})$ (model B2). The convention for the exclusion curves are same as in Fig. 5.

SAME SIGN: INTERPRETATION



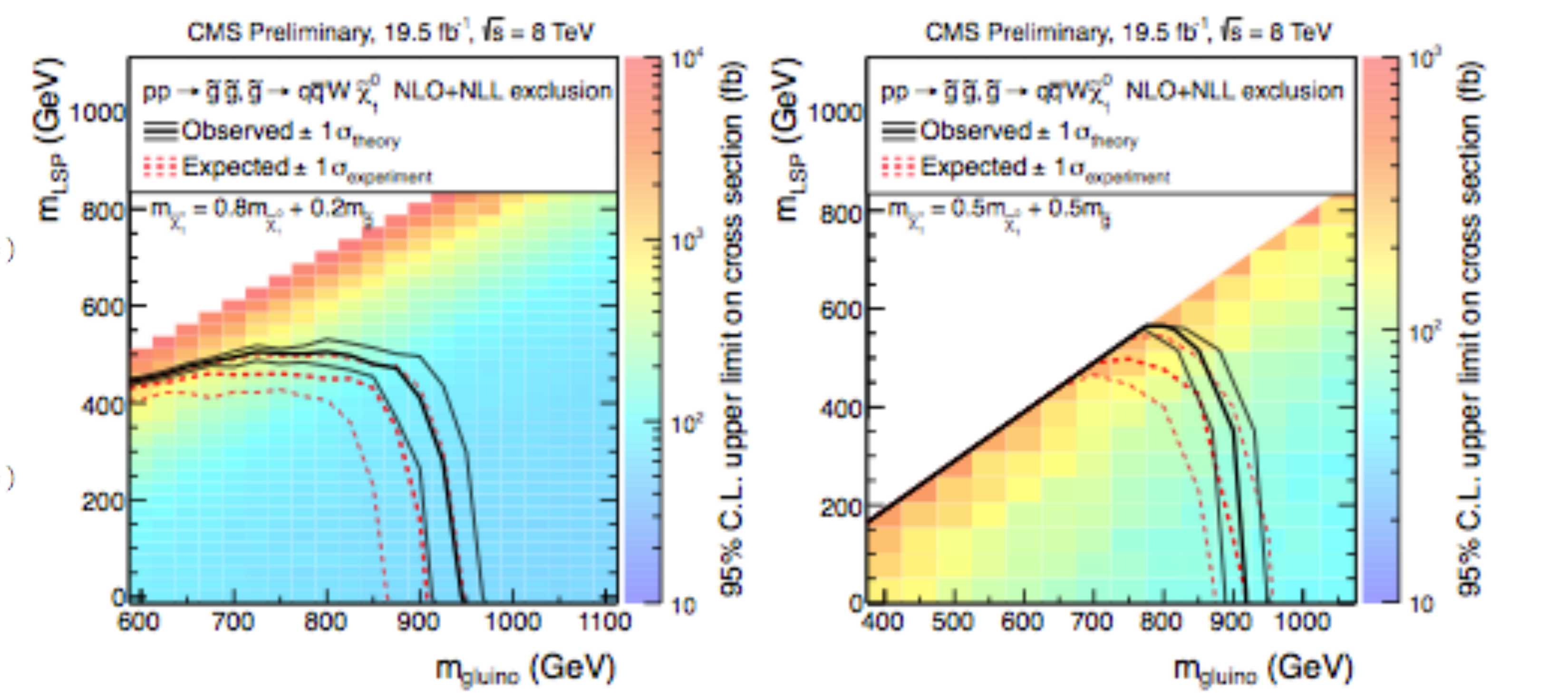
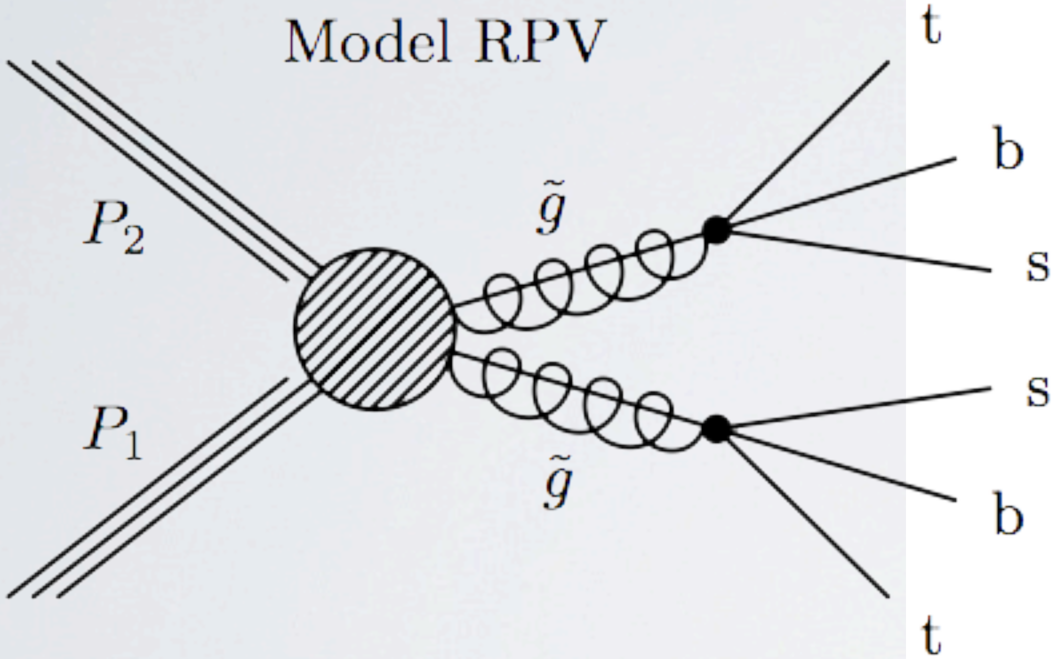


Figure 7: Exclusion regions at 95% CL in the planes of $m(\tilde{\chi}_1^0)$ *vs.* $m(\tilde{g})$ (model C1). The convention for the exclusion curves are same as in Fig. 5.

SAME SIGN: INTERPRETATION



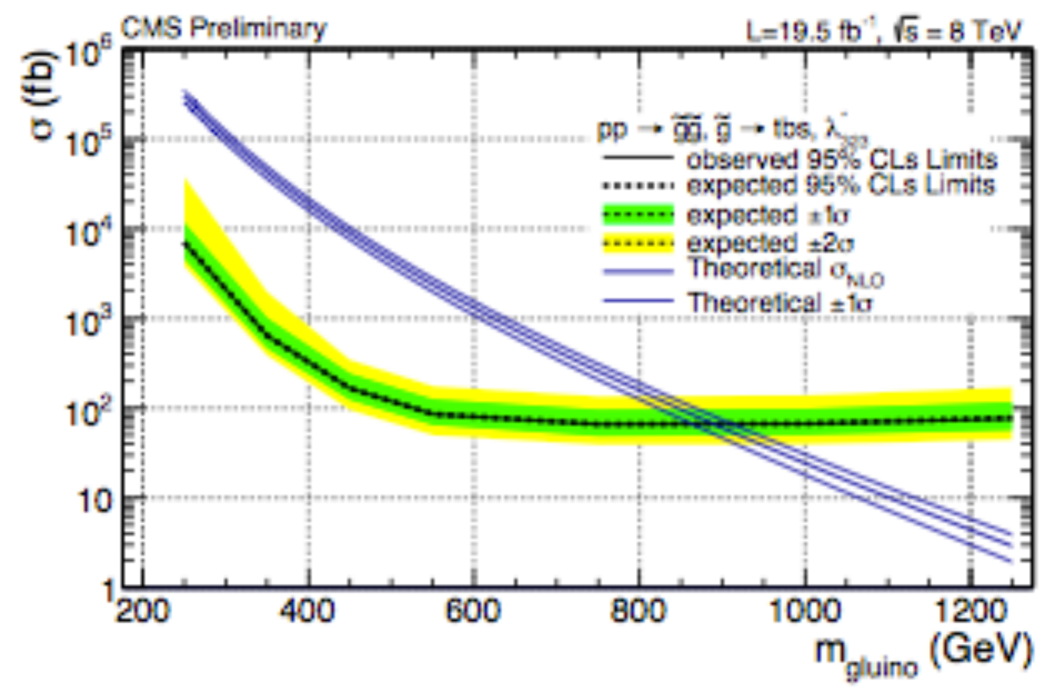


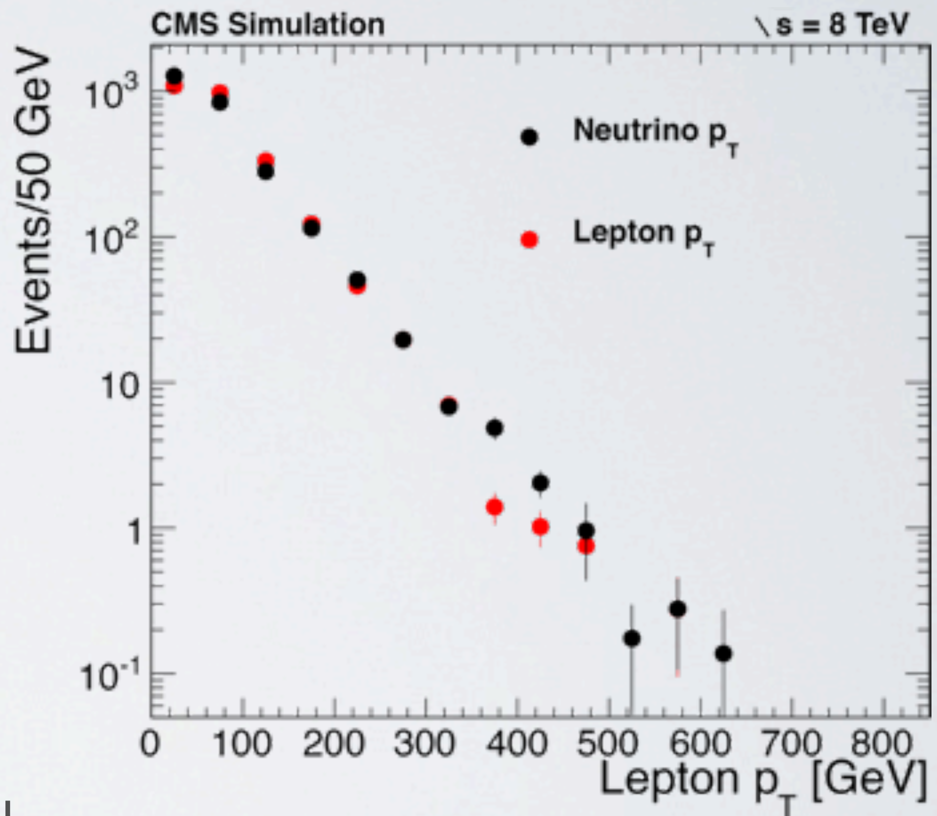
Figure 8: 95% CL upper limit on the gluino production cross section for an RPV simplified model, $pp \rightarrow \tilde{g}\tilde{g}, \tilde{g} \rightarrow tbs(\bar{t}\bar{b}\bar{s})$.

SL CMS

BACKUP

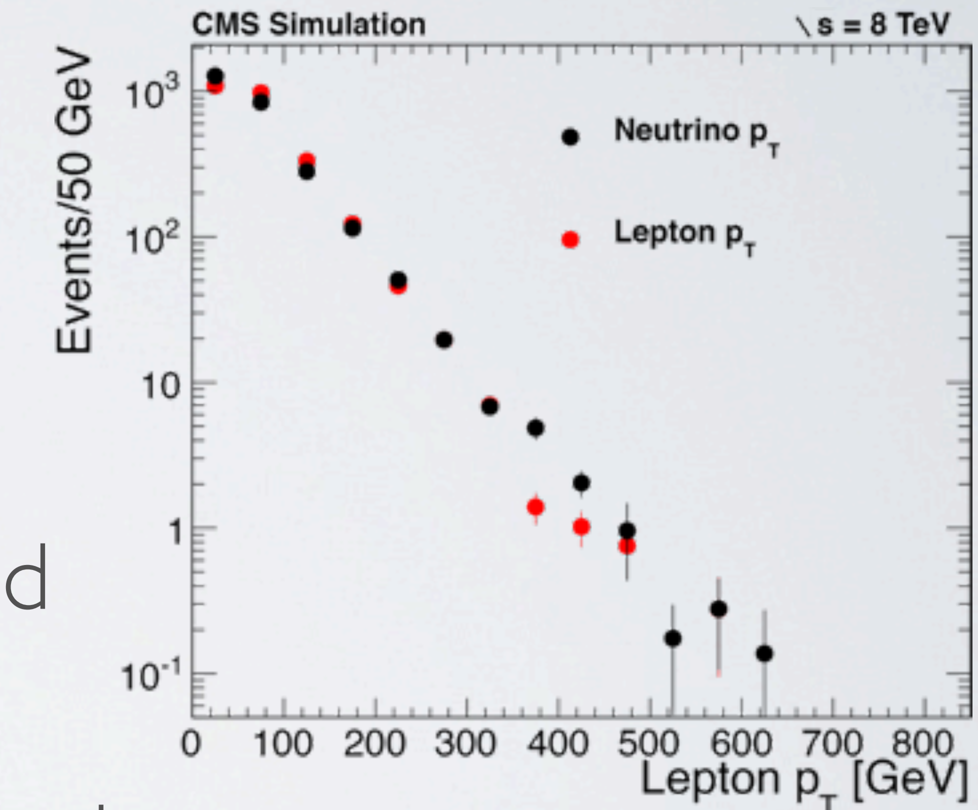
LEPTON SPECTRUM METHOD (I)

- Examine MET spectrum for events with large H_T
- Different cuts on MET and H_T to define signal regions
- Use observed lepton p_T distribution to predict MET distribution from single lepton top quark decays (dominant background)
- sub-dominant contribution from mis-reconstructed dilepton events (predicted from control sample)



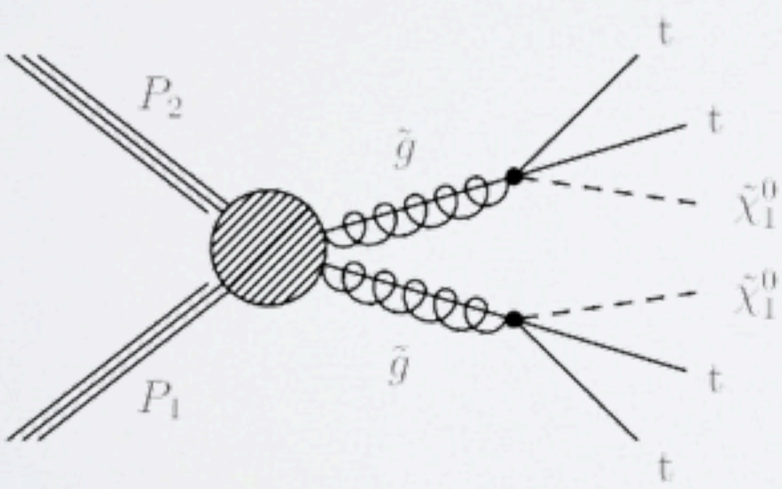
LEPTON SPECTRUM METHOD (II)

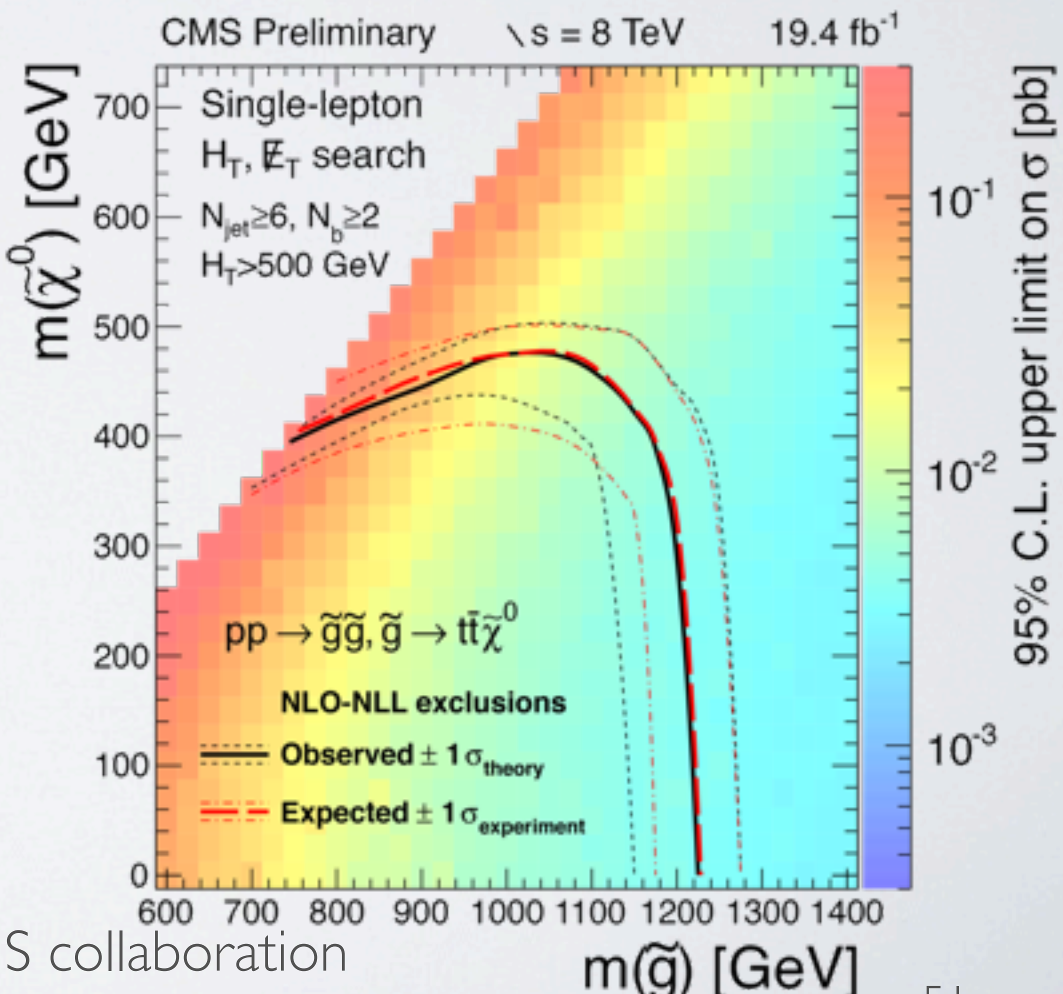
- Backgrounds:
  - Single lepton background
    - largest background, consists of top pair production with single lepton from W → lν
    - use similarity of neutrino and charged lepton p_T spectrum in W decays
    - correct for several effects, e.g. polarization



LEPTON SPECTRUM METHOD (III)

- Interpretation:
  - Considered simplified model benchmark of gluino pair production
  - Limits were set using most sensitive bin in H_T

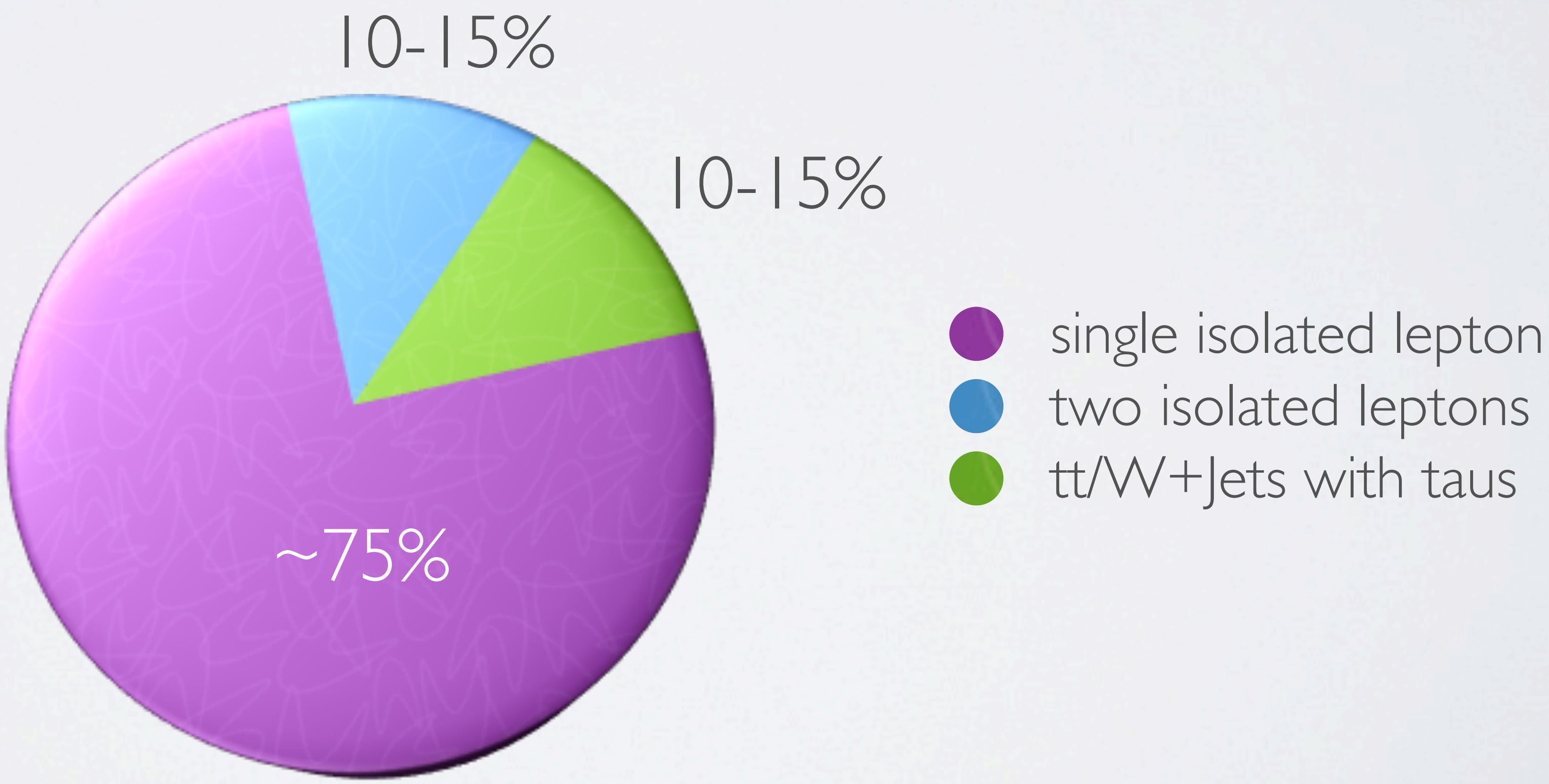




LEPTON SPECTRUM METHOD: BACKGROUNDS

After MET>250 GeV, H_T>500 GeV selection:

- primarily single isolated lepton (μ/e) either from tt or W+Jets
- events with two isolated leptons can feed down (10-15%)
- additional 10-15% from tt and W+Jets with tau leptons



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SL: SINGLE LEPTON PREDICTION

- Largest background (consists of top pair production with single lepton from W → lν)
- p_T of neutrino and charged lepton are very different on event-by-event basis, but distributions of the true neutrino p_T and the true lepton p_T are identical in the absence of W polarization
- Effects of W polarization well understood theoretically and well-modeled in MC
- Corrections derived for polarization, non-single lepton components which are not modeled by the method, the effect of a lepton pT threshold, difference between MET and lepton pT resolution
- Corrections applied using a scale factor (calculated in MC for each MET bin)
- Systematic uncertainties taken into account by calculating change induced in scale factor

SL: NEUTRINO & LEPTON SPECTRUM

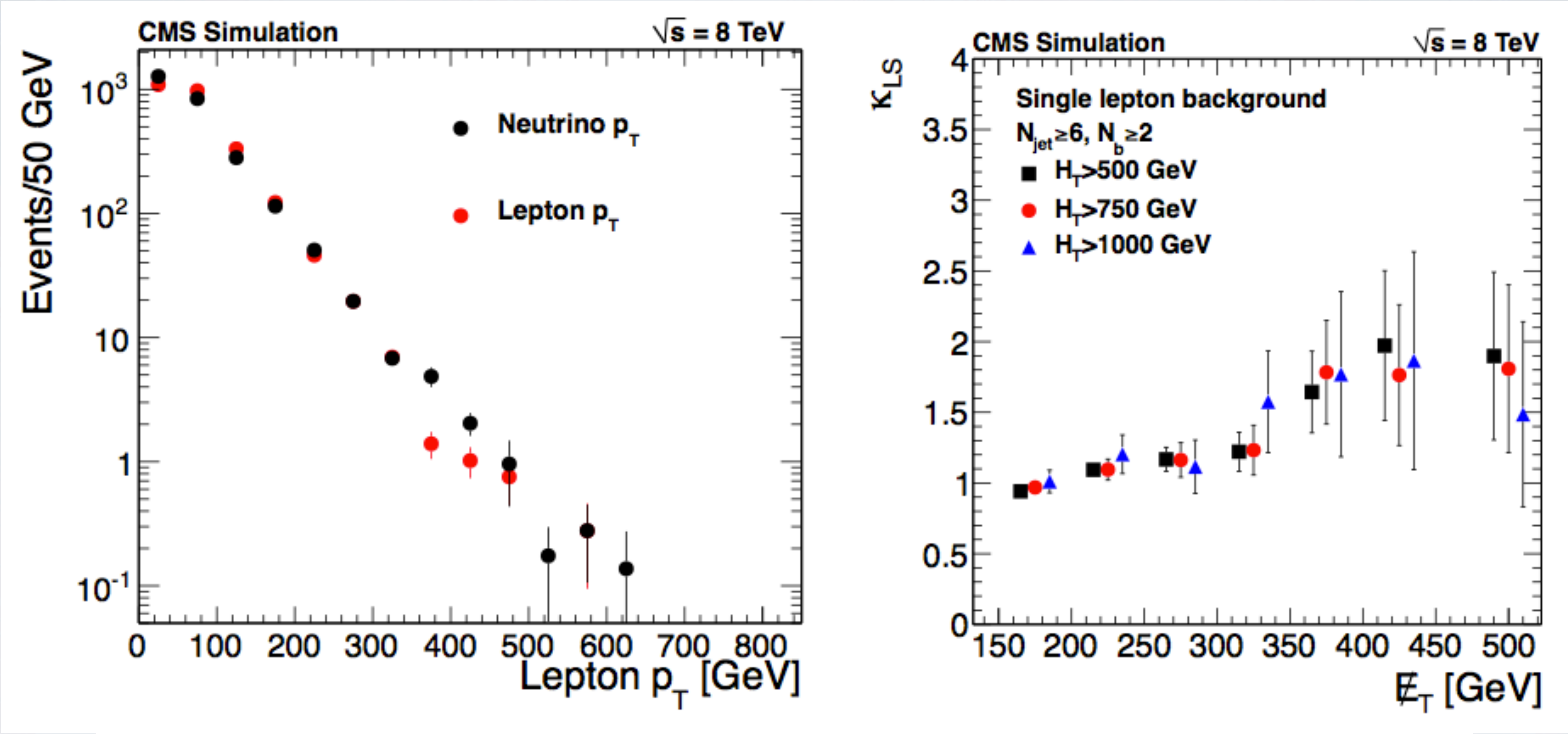

Figure 1: Left: Generator-level neutrino and charged lepton p_T distributions from simulated events. All background components are included and scaled to the data luminosity. Right: Scale factors used in the lepton spectrum prediction.

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SL: TAU LEPTON PREDICTION

- background contribution involving taus anot predicted by lepton spectrum method due to presence of extra neutrino(s) from tau decay
- measured using single lepton and dilepton control samples, where leptons are used to emulate tau decays using tau decay response functions (from MC)
- Different categories of tau backgrounds:
  - tau -> l
  - l+tau -> l
  - l+tau->hadrons
- Separate tau background predictions differ primarily in control sample and/or tau response function used

SL: BACKGROUNDS (I)

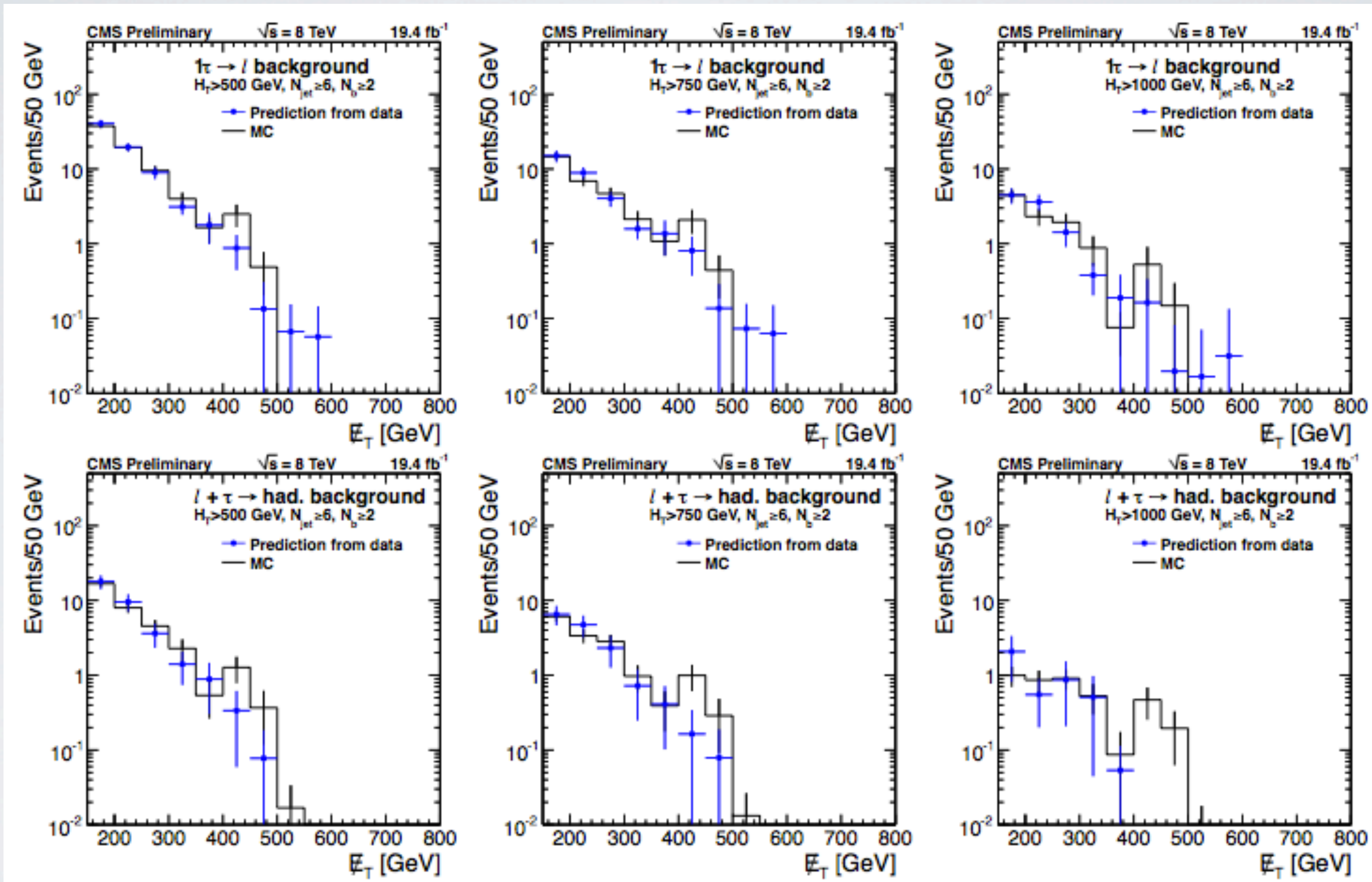
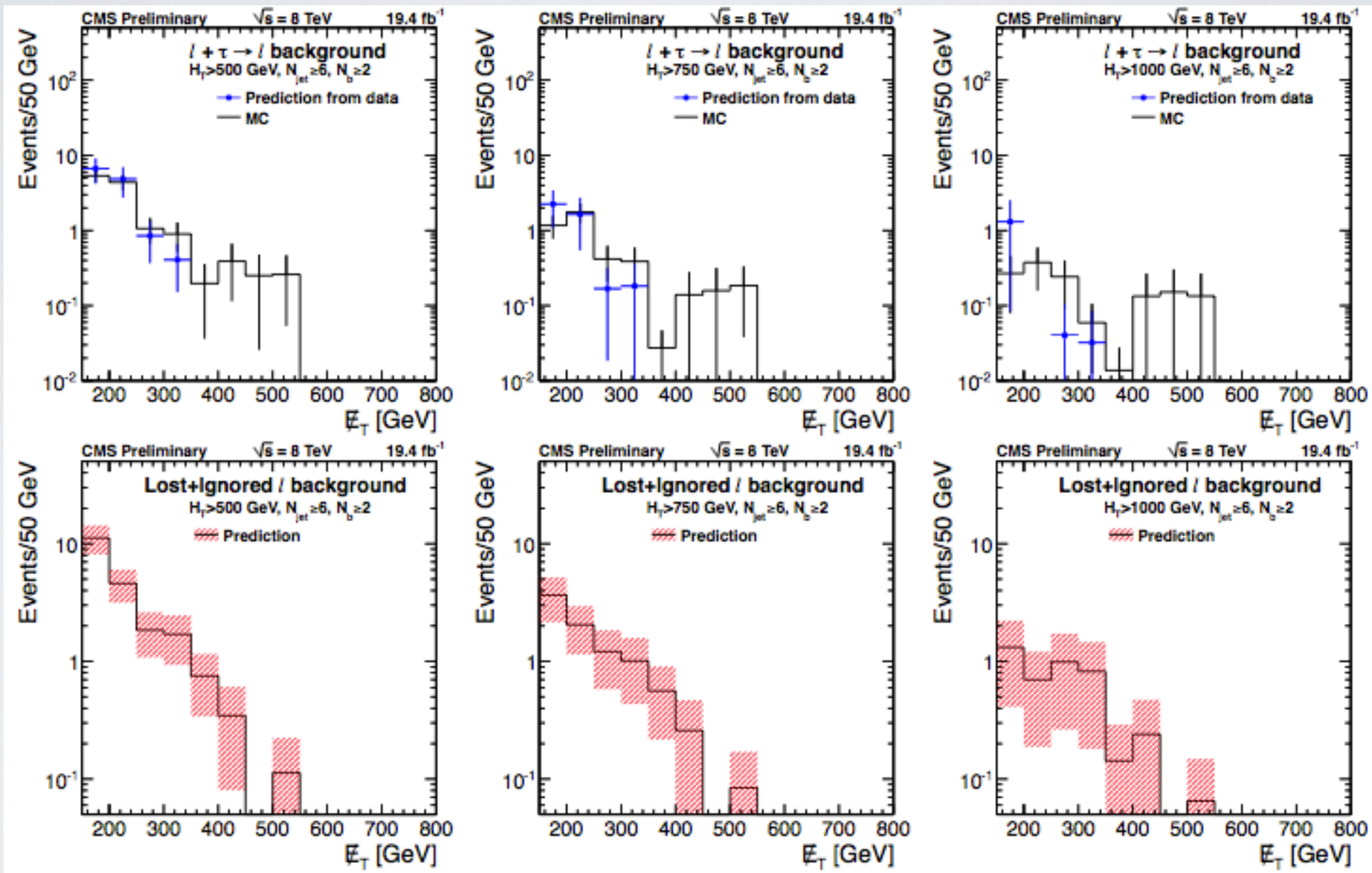


Figure 3: From top to bottom: Predicted $\tau \to \ell$ background, predicted $\ell + \tau \to$ hadrons background, predicted $\ell + \tau \to \ell$ background, $\not{E}_T$ distribution from simulation for ignored and lost leptons, scaled to the ratio of dilepton yields in data over MC. In the top three rows, the MC shapes are shown only for comparison; the simulation is not used directly.

note: MC shape not used in prediction

SL: BACKGROUNDS (II)



note:
MC shape
not used
in
prediction

Figure 3: From top to bottom: Predicted $\tau \rightarrow \ell$ background, predicted $\ell + \tau \rightarrow$ hadrons background, predicted $\ell + \tau \rightarrow \ell$ background, $\not{E}_T$ distribution from simulation for ignored and lost leptons, scaled to the ratio of dilepton yields in data over MC. In the top three rows, the MC shapes are shown only for comparison; the simulation is not used directly.

SL: LOST & IGNORED L PREDICTION

- two types of dilepton events without taus:
  - ignored lepton events: both leptons reconstructed, but one of the leptons falls outside of the lepton veto
  - lost lepton events: one lepton is not reconstructed
- prediction uses same dilepton control sample as in l+tau->l and l+tau->hadrons
- prediction obtained by normalizing MET distribution from simulation to number of 2l+jet events in data control sample
- Systematic uncertainties from uncertainty on data/MC scale factor, pileup distribution, lepton selection efficiencies and top p_T spectrum

SL: CLOSURE

- before looking at signal regions ($N_J \geq 6$), consider background dominated region ($N_J \geq 4$)
- plots on next slide

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SL: RESULTS WITH $N_J \geq 4$

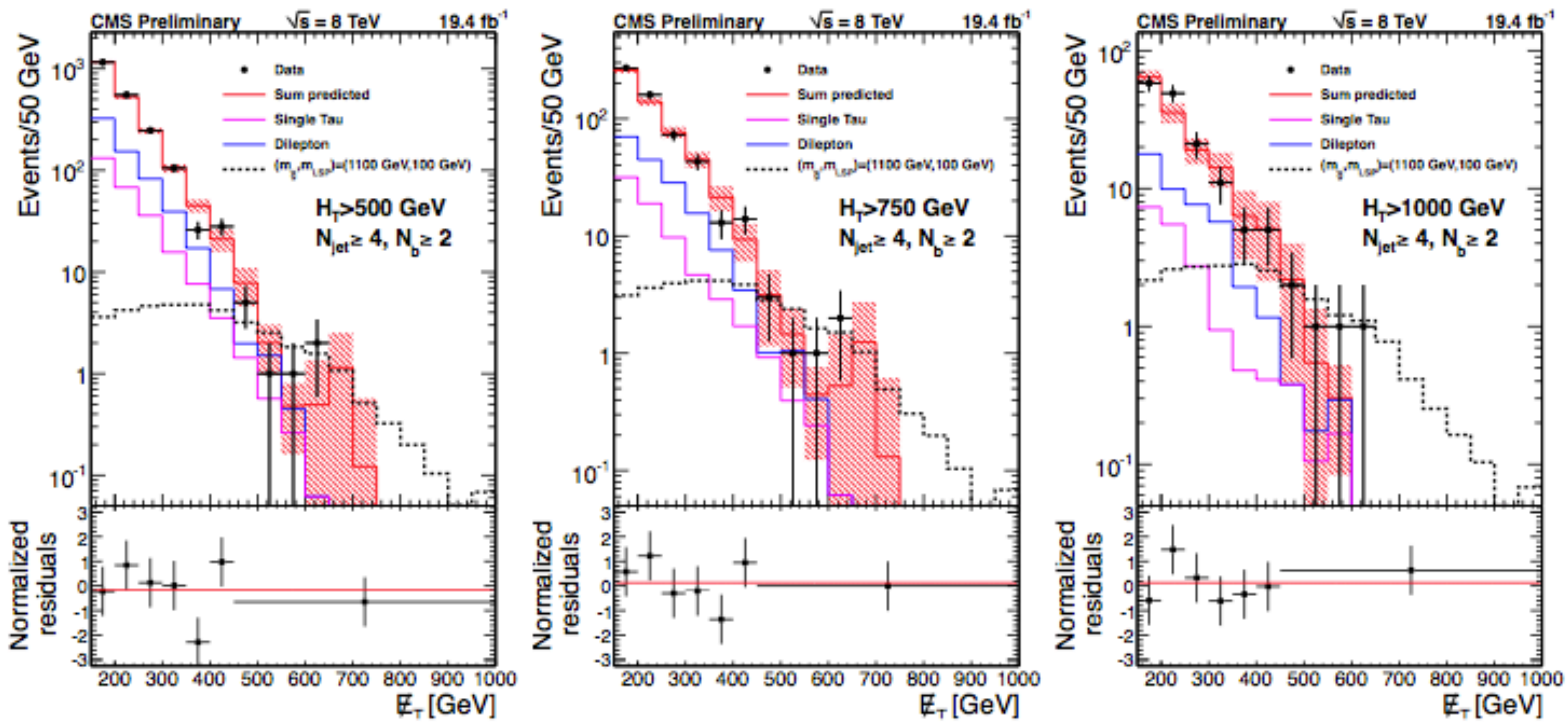

Figure 4: Data (dots with error bars) for $N_{\mathrm{jet}} \geq 4$ and $N_b \geq 2$. $H_T > 500$ GeV (left), $H_T > 750$ GeV (middle), $H_T > 1000$ GeV (right). The blue line is the contribution from dileptons and single taus. The purple line is the contribution from single taus. The red error band includes the statistical uncertainty in the variation of the jet/$\not\!\!E_{\mathrm{T}}$ scale and the p_{T} dependent single lepton scale factors applied. The $\not\!\!E_{\mathrm{T}}$ distribution from the $(m_{\tilde{g}}, m_{\tilde{\chi}^0}) = (1100\ \mathrm{GeV}, 100\ \mathrm{GeV})$ T1tttt model point is overlaid in black. The lower panes show the difference between observed and predicted yields divided by the uncertainty.

SL: SYSTEMATIC UNCERTAINTY

Table 1: Systematic uncertainties, in percent, for the single lepton background prediction for $H_T > (500/750/1000)$ GeV in the search $\not\!\!E_{\mathrm{T}}$ bins and the low $\not\!\!E_{\mathrm{T}}$ validation region. Each uncertainty is expressed as the change in the ratio of predicted to true number of events (evaluated using simulated events). Uncertainties associated with the tau and dilepton backgrounds are listed in Tables 2 and 3, respectively. The total uncertainty is the individual uncertainties summed in quadrature.

$\not\!\!E_{\mathrm{T}}$ bin:	[150, 250)	[250, 350)	[350, 450)	$\geq$ 450 GeV
$\not\!\!E_{\mathrm{T}}$ and jet energy scale	3.0/2.1/1.1	8.4/8.7/12	9.0/6.5/7.2	28/30/31
W polarization in $t\bar{t}$	3.1/3.4/4.3	4.1/4.1/3.9	5.2/5.8/4.9	5.2/5.4/3.2
W polarization in W+jets	<0.1/0.1/0.2	0.2/0.1/0.2	0.8/0.7/1.1	1.6/1.7/2.5
$\sigma(t\bar{t})$	0.9/1.3/1.1	0.5/1.1/2.1	0.3/0.1/0.7	1.3/1.0/1.6
$\sigma(\mathrm{W})$	0.4/0.5/0.4	0.2/0.4/0.8	1.1/0.4/1.3	1.2/0.3/1.2
Single top cross section	0.6/1.3/0.3	0.4/1.3/3.2	0.2/0.1/0.4	< 0.1/< 0.1/0.1
Lepton efficiency (μ) vs. p_{T}	0.5/0.5/0.5	0.5/0.5/0.6	0.5/0.5/0.8	0.2/0.2/0.7
Lepton efficiency (e) vs. p_{T}	0.2/0.2/0.2	0.2/0.2/0.2	0.2/0.2/0.1	0.3/0.3/0.2
Z+jets background	0.2/0.3/0.4	0.4/0.4/0.1	1.2/1.0/0.9	0.3/0.4/< 0.1
μ p_{T} resolution	<0.1/<0.1/<0.1	0.1/0.4/0.8	1.4/1.3/3.4	2.7/1.5/2.5
Total (excluding scale factors)	4.5/4.5/4.8	9.5/9.8/11	13/9.8/9.6	29/31/31
MC statistics (scale factors)	3.2/4.8/8.0	8.0/10/16	19/21/30	31/33/44
Total	5.5/6.6/9.3	12/14/19	23/23/31	42/45/54

SL: SYSTEMATIC UNCERTAINTY (TAU)

Table 2: Relative systematic uncertainties, in percent, on the $1\tau \rightarrow 1\ell$, $\ell + \tau \rightarrow \ell$, and $\ell + \tau \rightarrow$ hadrons background predictions for $N_{\text{jet}} \geq 6$ and $N_b \geq 2$. The relative uncertainty is shown for each of the H_T selections separated by slashes, i.e. $H_T > 500/750/1000$ GeV.

$\not{E}_T$ bin	$1\tau \rightarrow 1\ell$	$\ell + \tau \rightarrow \ell$	$\ell + \tau \rightarrow$ hadrons
[150, 250)	11/16/19	28/34/70	16/20/35
[250, 350)	16/19/29	37/65/131	21/25/35
[350, 450)	39/43/95	73/121/115	43/45/60
[450, ∞)	120/99/309	97/95/113	97/95/88

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SL: SCALE FACTORS

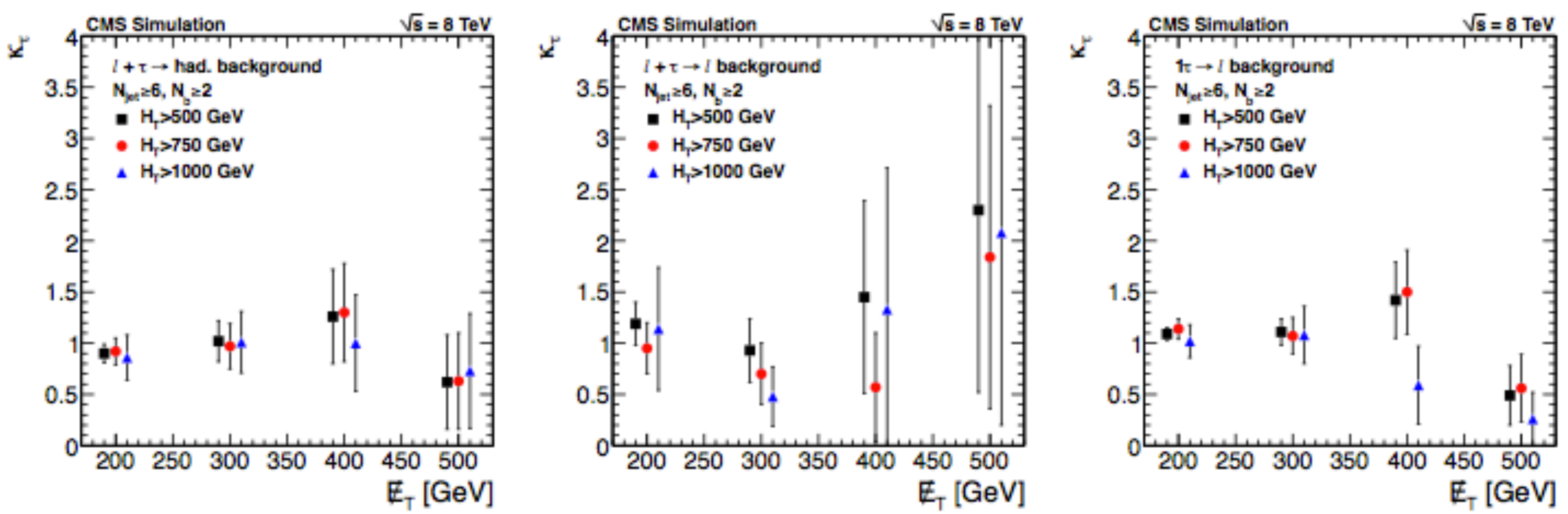

Figure 2: Scale factors used in the tau predictions are shown for $\ell + \tau \rightarrow$ hadrons (left), $\ell + \tau \rightarrow \ell$ (center) and $\tau \rightarrow \ell$ (right). The last bin corresponds to $\not{E}_T > 450$ GeV.

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SL: SYST UNCERTAINTY

Table 3: Relative systematic uncertainties, in percent, on the lost and ignored dilepton background predictions for $N_{jet} \geq 6$ and $N_b \geq 2$. The relative uncertainty is shown for each of the H_T selections separated by slashes, i.e. $H_T > 500/750/1000$ GeV.

$\not{E}_T$ bin	[150, 250)	[250, 350)	[350, 450)	≥ 450 GeV
Pile-up	1.1/1.2/2.7	3.3/5.7/6.8	2.2/3.0/5.9	43/42/48
Top-quark p_T	9.1/4.1/0.4	14/15/15	19/19/24	12/12/15
Lepton efficiency	4.8/4.9/4.7	6.0/5.5/4.1	2.8/2.8/3.5	8.5/7.9/2.0
Trigger efficiency	6.0/6.0/6.0	6.0/6.0/6.0	6.0/6.0/6.0	6.0/6.0/6.0
Data/MC scale factor	22/36/61	22/36/61	22/36/61	22/36/61
Total	25/37/62	28/40/64	30/41/66	51/57/79

SL:YIELDS

Table 4: Observed and predicted yields for $H_T > 500$ GeV. The yields are shown as **total** (μ channel, e channel). A requirement of $N_{\text{jet}} \geq 6$ and $N_b \geq 2$ is imposed. The contribution of QCD multijet events is omitted in the total predicted yields.

$\not{E}_T$:	[150,250)	[250,350)	[350,450)	≥ 450 GeV
$1\ \ell$	304.0±17.4±16.4	49.9±7.7±6.0	13.4±4.8±3.1	$0.3^{+1.9+0.8}_{-0.3-0.3}$
Dilepton	54.7±4.2±9.0	9.6±1.5±4.4	$2.3^{+1.3+1.0}_{-0.7-0.6}$	$0.1^{+1.8+1.8}_{-0.1-0.1}$
Single tau	60.1±2.1±5.1	11.8±0.9±3.6	2.7±0.5±1.9	0.3±0.1±0.1
Z+jets (from MC)	0.5±0.1±0.5	< 0.1	< 0.1	< 0.1
QCD multijet	1.6 ± 3.1 ± 3.1		0.0 ± 1.2 ± 1.2	
Total (predicted):	419.3±18.0±19.4	71.3±7.9±8.3	$18.4^{+5.0+3.8}_{-4.9-3.7}$	$0.7^{+2.6+2.0}_{-0.3-0.3}$
Data (observed), **total** (μ, e):	**437** (237, 200)	**72** (38, 34)	**12** (7, 5)	**1** (0, 1)
SMS ($m_{\tilde{g}} = 1150$ GeV, $m_{\text{LSP}} = 500$ GeV)	5.1±0.2	5.6±0.2	3.7±0.2	3.0±0.2
SMS ($m_{\tilde{g}} = 1100$ GeV, $m_{\text{LSP}} = 100$ GeV)	6.5±0.3	7.6±0.3	7.3±0.3	9.1±0.3

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SL:YIELDS

Table 5: Observed and predicted yields for $H_T > 750$ GeV. The yields are shown as **total** (μ channel, e channel). A requirement of $N_{\text{jet}} \geq 6$ and $N_b \geq 2$ is imposed.

$\not{E}_T$:	[150,250)	[250,350)	[350,450)	$\geq$ 450 GeV
1 ℓ	107.3±10.4±7.0	21.7±5.1±3.0	8.6±4.0±2.1	$0.3^{+1.8+0.8}_{-0.3-0.3}$
Dilepton	21.1±2.5±3.7	5.5±1.2±2.1	$1.4^{+0.7+0.8}_{-0.4-0.5}$	$0.0^{+1.8+1.7}_{-0.0-0.0}$
Single tau	24.2±1.4±3.6	5.5±0.6±1.0	2.2±0.4±0.6	0.3±0.1±0.1
Z+jets (from MC)	0.2±0.1±0.2	< 0.1	< 0.1	< 0.1
QCD multijet	< 1	< 0.1	< 0.1	< 0.1
Total (predicted):	152.7±10.7±8.7	32.7±5.3±3.9	$12.3\pm4.0^{+2.3}_{-2.2}$	$0.7^{+2.5+1.9}_{-0.3-0.3}$
Data (observed), **total** (μ, e):	**180** (94, 86)	**39** (19, 20)	**11** (7, 4)	**1** (0, 1)
SMS ($m_{\tilde{g}} = 1150$ GeV, $m_{\text{LSP}} = 500$ GeV)	3.3±0.2	3.7±0.2	2.6±0.1	2.7±0.2
SMS ($m_{\tilde{g}} = 1100$ GeV, $m_{\text{LSP}} = 100$ GeV)	5.8±0.3	6.9±0.3	6.6±0.3	8.6±0.3

SL: SYSTEMATIC UNCERTAINTY (TAU)

Table 6: Observed and predicted yields for $H_T > 1000$ GeV. The yields are shown as **total** (μ channel, e channel). A requirement of $N_{\rm jet} \geq 6$ and $N_b \geq 2$ is imposed.

$\not\!\!E_T$:	[150,250)	[250,350)	[350,450)	$\geq$ 450 GeV
1 ℓ	38.2±6.5±3.6	9.0±3.5±1.7	1.8±1.8±0.6	$0.0^{+1.5+0.8}_{-0.0-0.0}$
Dilepton	6.1±1.5±1.8	$3.3^{+1.0}_{-0.9} \pm 1.3$	$0.4^{+1.3+1.3}_{-0.4-0.3}$	$0.0^{+1.8+2.0}_{-0.0-0.0}$
Single tau	8.2±0.8±1.1	1.9±0.4±0.4	0.3±0.1±0.3	< 0.1
Z+jets (from MC)	< 0.1	< 0.1	< 0.1	< 0.1
QCD multijet	< 0.1	< 0.1	< 0.1	< 0.1
Total (predicted):	52.5±6.7±4.2	14.2±3.6±2.2	$2.5^{+2.2+1.5}_{-1.8-0.7}$	$0.2^{+2.3+2.2}_{-0.2-0.0}$
Data (observed), **total** (μ, e):	**61** (29, 32)	**16** (7, 9)	**5** (3, 2)	**1** (0, 1)
SMS ($m_{\tilde{g}} = 1150$ GeV, $m_{\rm LSP} = 500$ GeV)	1.2±0.1	1.3±0.1	1.1±0.1	1.5±0.1
SMS ($m_{\tilde{g}} = 1100$ GeV, $m_{\rm LSP} = 100$ GeV)	4.2±0.2	4.7±0.2	4.7±0.2	6.6±0.3

SL: RESULTS WITH $N_J \geq 6$

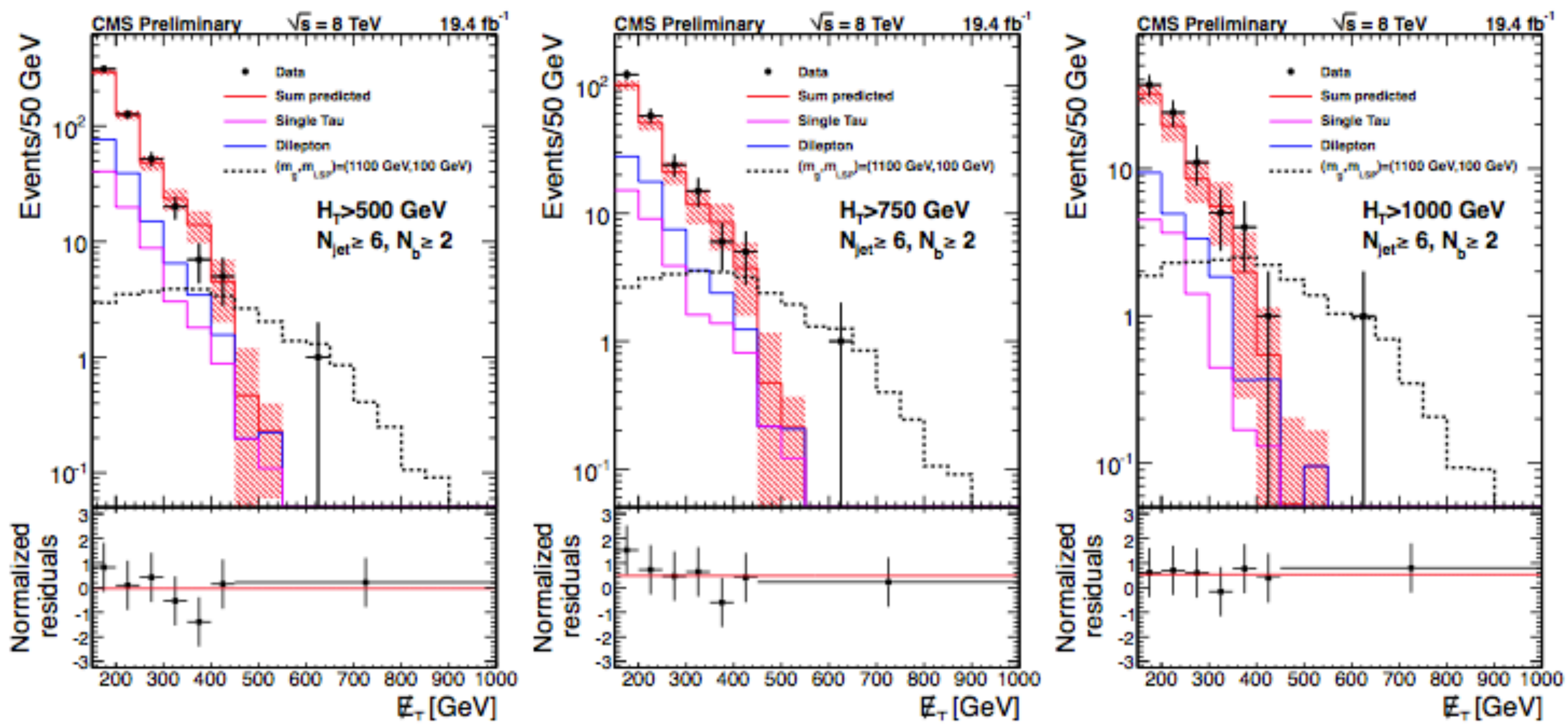

Figure 5: Data (dots with error bars) for $N_{\text{jet}} \geq 6$ and $N_b \geq 2$. $H_T > 500$ GeV (left), $H_T > 750$ GeV (middle), $H_T > 1000$ GeV (right). The blue line is the contribution from dileptons and single taus. The purple line is the contribution from single taus. The red error band includes the statistical uncertainty in the variation of the jet/$\not\!\!E_{\mathrm{T}}$ scale and the p_{T} dependent single lepton scale factors applied. The $\not\!\!E_{\mathrm{T}}$ distribution from the $(m_{\tilde{g}}, m_{\tilde{\chi}^0}) = (1100\text{ GeV}, 100\text{ GeV})$ T1tttt model point is overlaid in black. The lower panes show the difference between observed and predicted yields divided by the uncertainty.

SL: EXCLUSION

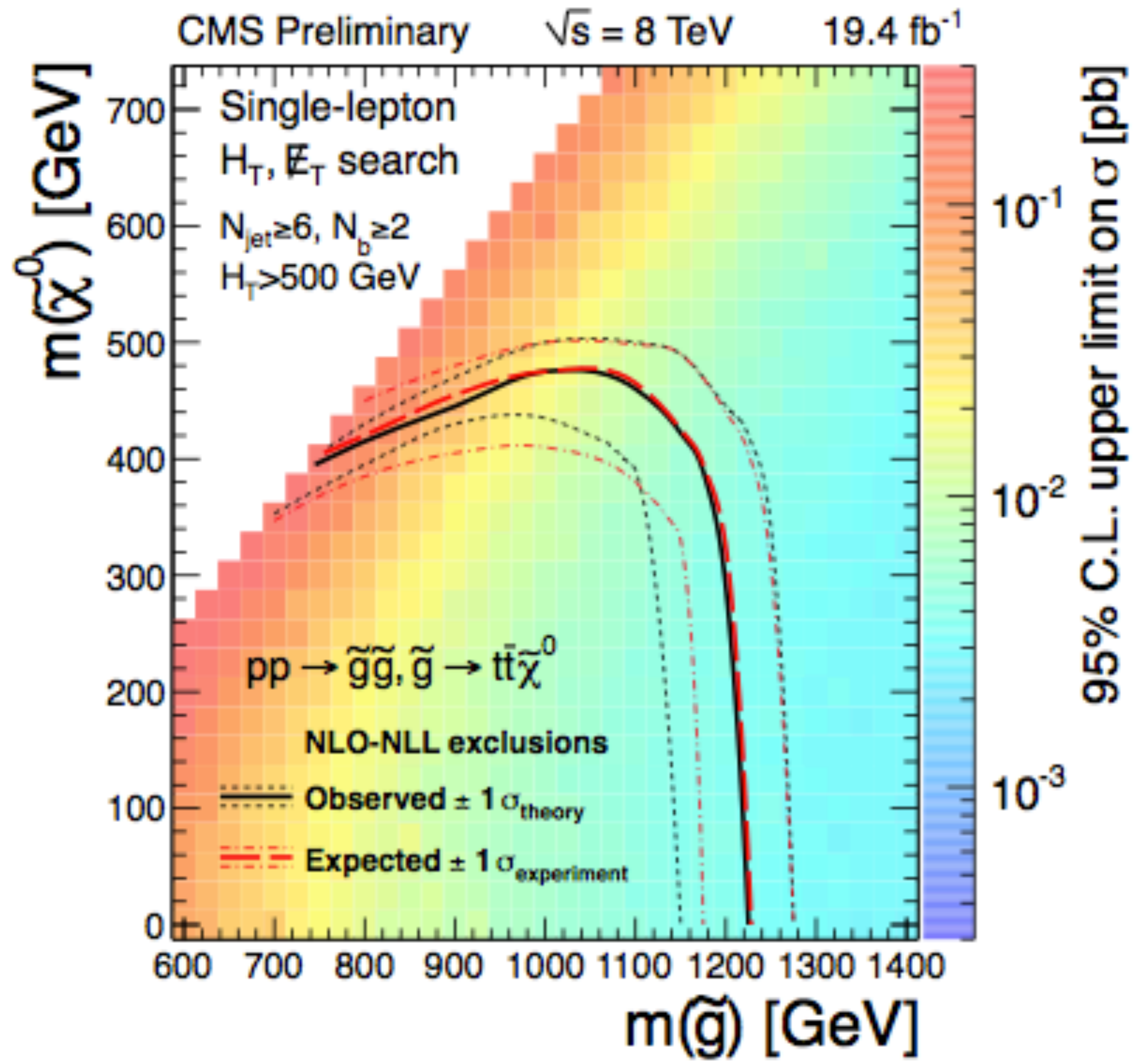

Figure 6: 95% C.L. upper limits on the production cross section for $N_{jet} \geq 6$, and $N_b \geq 2$ in the T1tttt model. The limit at each point comes from the H_T selection that gives the best expected limit. The z axis corresponds to the observed limit. The observed ($\pm 1\sigma$ theory) and expected ($\pm 1\sigma$ experimental) limit contours are also shown.

SL: DELTA PHI DISTRIBUTIONS

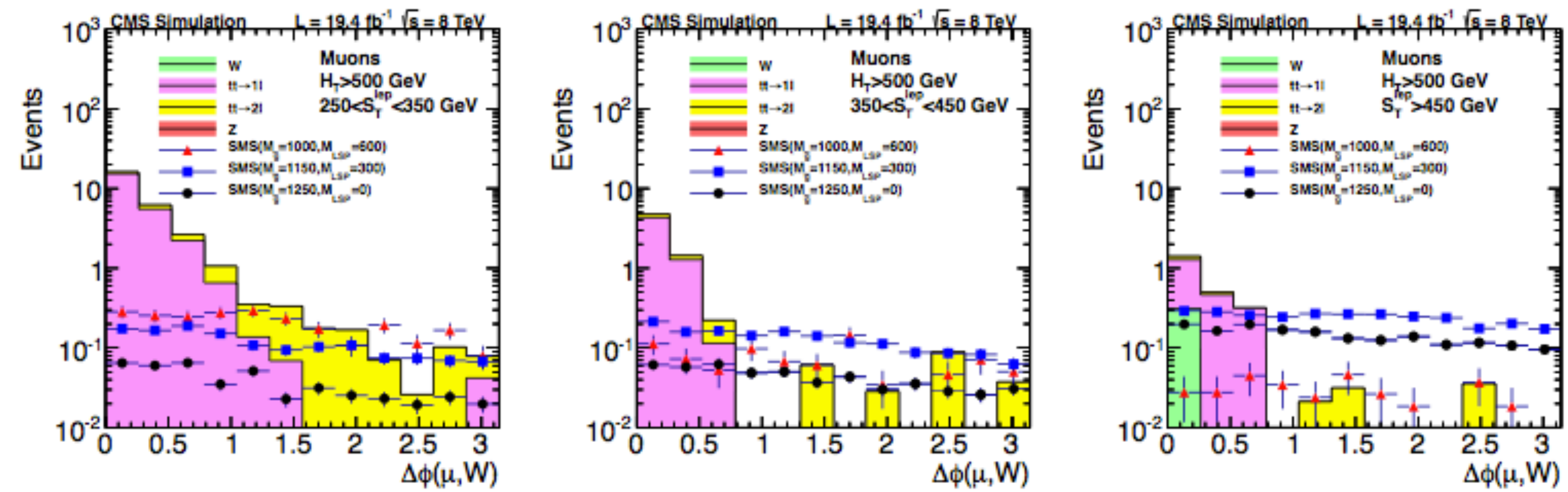

Figure 7: The $\Delta\phi(W,\ell)$ distribution for muon events with $N_{\mathrm{b}} \geq 3$ and $N_{\mathrm{jet}} \geq 6$. Left: 250 GeV $< S_{\mathrm{T}}^{lep} < 350$ GeV, center: 350 GeV $< S_{\mathrm{T}}^{lep} < 450$ GeV and right: 450 GeV $< S_{\mathrm{T}}^{lep}$.

SL: EVENTS YIELDS (MUONS)

Table 7: Event yields in the muon channel, as expected from simulation for an integrated luminosity of 19.4 fb^{-1}, for $N_{\text{jet}} \geq 6$ and $N_{\text{b}} \geq 3$. The column "R_{CS}" lists the ratio of yields in the signal ($\Delta\phi(W,\ell) > 1$) and control ($\Delta\phi(W,\ell) < 1$) regions. The numbers in brackets for the SMS points indicate the gluino and LSP masses in GeV. The uncertainties are statistical only.

	$250 < S_T^{lep} < 350$ GeV			$350 < S_T^{lep} < 450$ GeV			$S_T^{lep} > 450$ GeV		
sample	signal	control	R_{CS}	signal	control	R_{CS}	signal	control	R_{CS}
$t\bar{t}$ (1ℓ)	0.4 ± 0.1	23.5 ± 1.3	0.02	< 0.07	5.7 ± 0.7	-	< 0.01	1.7 ± 0.4	-
$t\bar{t}$ $(\ell\ell)$	1.2 ± 0.2	2.2 ± 0.3	0.56	0.2 ± 0.1	0.7 ± 0.2	0.31	0.1 ± 0.1	0.2 ± 0.1	0.54
W	<0.32	< 0.32	-	< 0.33	< 0.33	-	< 0.29	0.3 ± 0.3	-
Z	<0.04	< 0.04	-	< 0.04	< 0.04	-	< 0.06	< 0.06	-
tW	0.3 ± 0.2	0.9 ± 0.2	0.35	< 0.08	0.6 ± 0.2	0.00	< 0.08	0.2 ± 0.1	0.05
single t	<0.05	< 0.05	0.32	< 0.05	< 0.05	-	< 0.01	< 0.01	-
SM all	1.9 ± 0.3	26.7 ± 1.3	0.07	0.2 ± 0.1	7.0 ± 0.8	0.03	0.1 ± 0.1	2.4 ± 0.5	0.04
SMS(1000,600)	1.4 ± 0.1	1.0 ± 0.1	1.38	0.5 ± 0.1	0.3 ± 0.1	1.49	0.2 ± 0.0	0.1 ± 0.0	1.39
SMS(1150,300)	0.7 ± 0.0	0.7 ± 0.0	1.10	0.9 ± 0.0	0.7 ± 0.0	1.30	1.9 ± 0.1	1.0 ± 0.1	1.84
SMS(1250,0)	0.2 ± 0.0	0.2 ± 0.0	1.00	0.3 ± 0.0	0.2 ± 0.0	1.26	1.0 ± 0.0	0.7 ± 0.0	1.44

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SL: EVENTS YIELDS (ELECTRONS)

Table 8: Event yields in the electron channel, as expected from simulation for an integrated luminosity of 19.4 fb^{-1}, for $N_{\text{jet}} \geq 6$ and $N_b \geq 3$. The numbers in brackets for the SMS points indicate the gluino and LSP masses in GeV. The uncertainties are statistical only.

	$250 < S_T^{lep} < 350$ GeV			$350 < S_T^{lep} < 450$ GeV			$S_T^{lep} > 450$ GeV		
sample	signal	control	R_{CS}	signal	control	R_{CS}	signal	control	R_{CS}
$t\bar{t}$ (1ℓ)	0.4 ± 0.2	19.8 ± 1.2	0.02	0.1 ± 0.1	6.0 ± 0.7	0.01	< 0.13	1.7 ± 0.4	-
$t\bar{t}$ ($\ell\ell$)	0.8 ± 0.2	1.8 ± 0.3	0.45	0.3 ± 0.1	0.8 ± 0.2	0.36	0.1 ± 0.1	0.4 ± 0.2	0.27
W	<0.33	< 0.33	-	< 0.34	0.4 ± 0.4	-	< 0.33	< 0.33	-
Z	<0.04	< 0.04	-	< 0.03	< 0.03	-	< 0.03	< 0.03	-
QCD	<0.05	< 0.05	-	< 0.01	< 0.01	-	< 0.01	< 0.01	-
tW	0.1 ± 0.1	0.8 ± 0.2	0.12	< 0.08	0.2 ± 0.1	-	< 0.08	0.2 ± 0.1	0.03
single t	<0.05	0.2 ± 0.1	-	< 0.01	< 0.01	-	< 0.01	< 0.01	-
SM all	1.4 ± 0.3	22.6 ± 1.2	0.06	0.4 ± 0.1	7.4 ± 0.8	0.05	0.1 ± 0.1	2.3 ± 0.4	0.05
SMS(1000,600)	1.5 ± 0.1	0.7 ± 0.1	2.08	0.5 ± 0.1	0.3 ± 0.1	1.61	0.2 ± 0.0	0.1 ± 0.0	2.16
SMS(1150,300)	0.7 ± 0.0	0.5 ± 0.0	1.38	0.9 ± 0.0	0.5 ± 0.0	1.62	1.7 ± 0.1	0.8 ± 0.0	2.09
SMS(1250,0)	0.2 ± 0.0	0.2 ± 0.0	1.25	0.3 ± 0.0	0.2 ± 0.0	1.55	0.8 ± 0.0	0.5 ± 0.0	1.65

SL: TRANSFER FACTOR

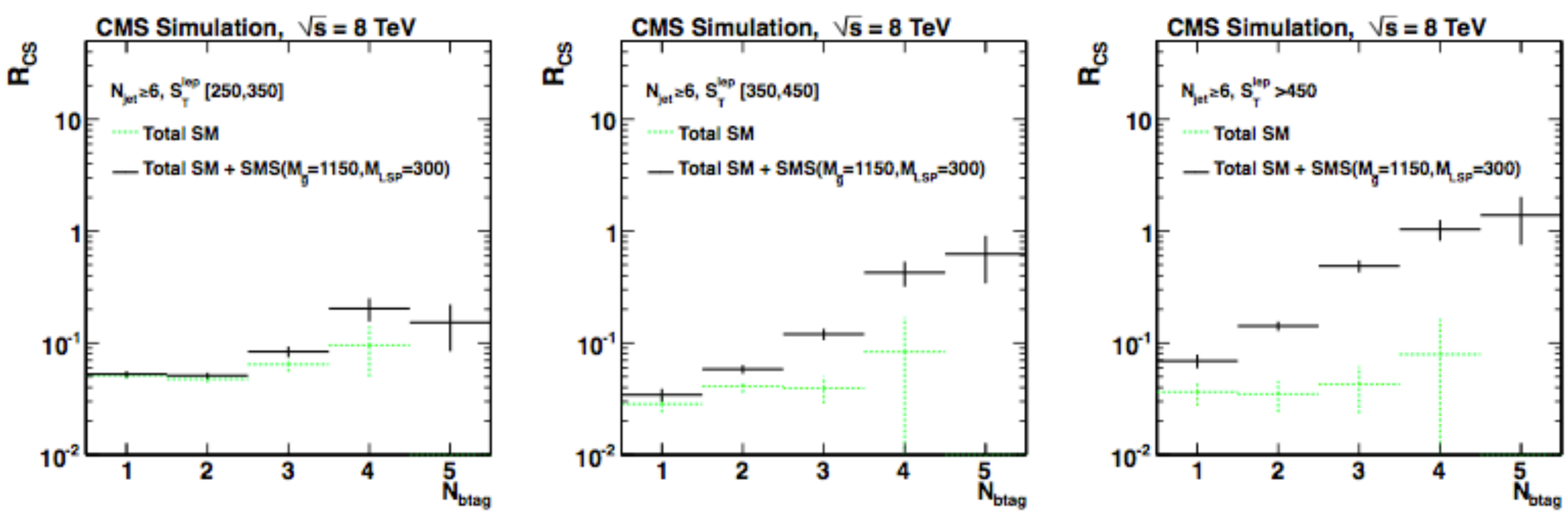


Figure 8: The transfer factor, R_{CS}, as a function of N_b for events with $N_{jet} \geq 6$, for electrons and muons combined. From left to right are the three S_T^{lep} bins, [250,350], [350,450] and S_T^{lep} >450 GeV respectively.

SL: DATA YIELDS

Table 9: Data yields and the corresponding R_{CS} for events with $N_{jet} \geq 6$ and $N_b = 1$.

		S_T^{lep} [GeV]	control	signal	R_{CS}
N_b=1	Muons	[250,350]	192	9	0.05 ± 0.02
		[350,450]	55	2	0.04 ± 0.03
		>450	10	0	<0.1
	Electr.	[250,350]	169	6	0.04 ± 0.01
		[350,450]	44	3	0.07 ± 0.04
		>450	17	0	<0.06

SL: CLOSURE

Table 10: Closure of the background estimation method in simulation, for both muons and electrons, comparing the yields in the signal region of events with $N_b \geq 3$ and the estimate using R_{CS} from the $N_b = 1$ sample. The κ_{CS} factor is the ratio of the "true" and "predicted".

S_T^{lep} [GeV]	sample	predicted	true	κ_{CS} factor
N_b=2				
[250,350]	Muons	7.56±0.68	6.87±0.56	0.91±0.14
[350,350]	Muons	1.03±0.29	1.63±0.26	1.57±0.51
>450	Muons	0.51±0.18	0.46±0.21	0.89±0.51
[250,350]	Electrons	7.78±0.83	7.37±0.72	0.95±0.14
[350,450]	Electrons	1.08±0.19	1.43±0.24	1.32±0.32
>450	Electrons	0.39±0.15	0.41±0.16	1.04±0.56
$N_b \geq 3$				
[250,350]	Muons	1.34±0.15	1.96±0.35	1.46±0.30
[350,350]	Muons	0.19±0.06	0.22±0.09	1.20±0.58
>450	Muons	0.09±0.04	0.10±0.05	1.11±0.74
[250,350]	Electrons	1.26±0.15	1.40±0.26	1.11±0.24
[350,450]	Electrons	0.25±0.05	0.42±0.15	1.69±0.68
>450	Electrons	0.09±0.04	0.12±0.07	1.38±0.94

SL: DATA YIELDS (CONTROL REGION)

Table 11: Data yields in control region, predicted event yields and observation yields in the signal region for events with $3 \leq N_{jet} \leq 5$. The uncertainties shown only reflect the statistical uncertainty stemming from the control region event counts in data.

		S_T^{lep} [GeV]	control reg. data	prediction	observation
N_b=2	Muons	[250,350]	632	41.94± 5.63	59
		[350,450]	188	8.51± 2.39	11
		> 450	71	2.46± 1.32	1
	Electr.	[250,350]	548	34.23±5.37	30
		[350,450]	174	5.11±1.85	8
		>450	61	5.57±2.14	1
$N_b \geq 3$	Muons	[250,350]	59	3.88±0.81	5
		[350,450]	25	1.09±0.44	0
		> 450	7	0.26±0.21	0
	Electr.	[250,350]	70	3.91±0.92	2
		[350,450]	12	0.32±0.16	2
		>450	4	0.32±0.24	0

SL: DATA YIELDS (SIGNAL REGION)

Table 12: Event yields in 19.4 fb^{-1} of data with $N_{jet} \geq 6$: the columns list the numbers of events observed in the control region, while for the signal region both the numbers of events expected and the numbers of events observed are listed. The uncertainty reflects the total uncertainty, while the number in parenthesis the statistical uncertainty stemming from the number of events in the control regions.

		S_T^{lep} [GeV]	control reg. data	prediction	observation
N_b=2	Muons	[250,350]	141	6.00 ± 2.40 (2.23)	9
		[350,450]	24	1.37 ± 1.19 (1.12)	2
		>450	9	0.0 ± 0.66 (0.66)	0
	Electr.	[250,350]	112	3.83 ± 1.84 (1.75)	9
		[350,450]	28	2.74 ± 2.02 (1.86)	2
		>450	9	0.0 ± 0.42 (0.42)	0
$N_b \geq 3$	Muons	[250,350]	28	1.92 ± 0.95 (0.84)	0
		[350,450]	13	0.57 ± 0.58 (0.52)	0
		>450	2	0.0 ± 0.22 (0.22)	0
	Electr.	[250,350]	45	1.89 ± 1.03 (0.94)	4
		[350,450]	7	0.85 ± 0.80 (0.70)	0
		>450	0	0.0 ± 0.08 (0.08)	0

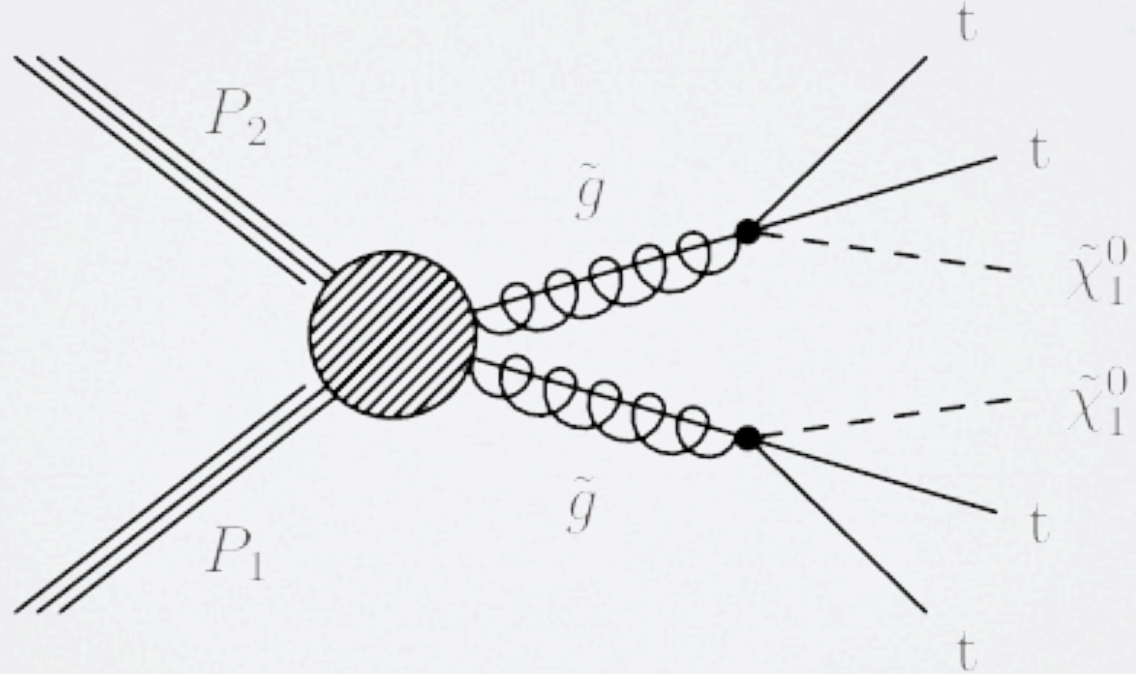
SL: SYST. UNCERTAINTY (κ_{CS})

Table 13: Systematic uncertainties of the κ_{CS} factor for events with $N_b \geq 3$. The two lepton flavors are combined.

	$\Delta\kappa_{CS}/\kappa_{CS}$ (%)		
	$250 < S_T^{lep} < 350\,\text{GeV}$	$350 < S_T^{lep} < 450\,\text{GeV}$	$450\,\text{GeV} < S_T^{lep}$
MC sample size	22	44	68
JES	3	7	6
ϵ_{btag}(c,b)	<1	<1	1
ϵ_{btag}(light)	<1	2	2
W cross-section	2	3	6
W+$b\bar{b}$ cross-section	2	4	7
Wt and t cross-section	4	6	11
Total	23	45	70

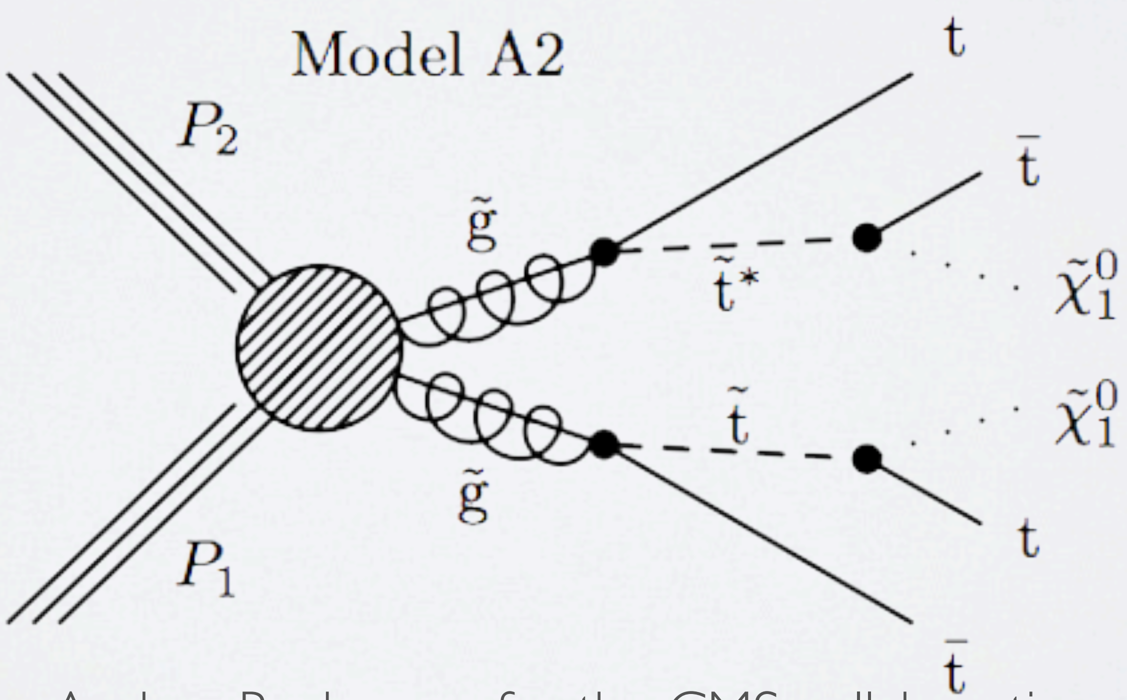
ABOUT THE MODEL

- Used Simplified Model of Supersymmetry (SMS)
  - represents decay chains of new particles (which may occur in a broad range of BSM physics scenarios)
- Gluino undergoes three-body decay $\tilde{g} \to t\bar{t}\chi_1^0$ mediated by off-shell top quark
- Four on-shell W bosons and four b quarks



ABOUT THE MODEL

- Used Simplified Model of Supersymmetry (SMS)
  - represents decay chains of new particles (which may occur in a broad range of BSM physics scenarios)
- gluino decays to a top quark and an anti-top squark, with the on-shell anti-squark further decaying into an anti-top quark and a neutralino
- Four on-shell W bosons and four b quarks



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