SUSY Same-sign lepton signatures and electroweakino searches in CMS experiment

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Universidad de Oviedo

CMS

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Motivation

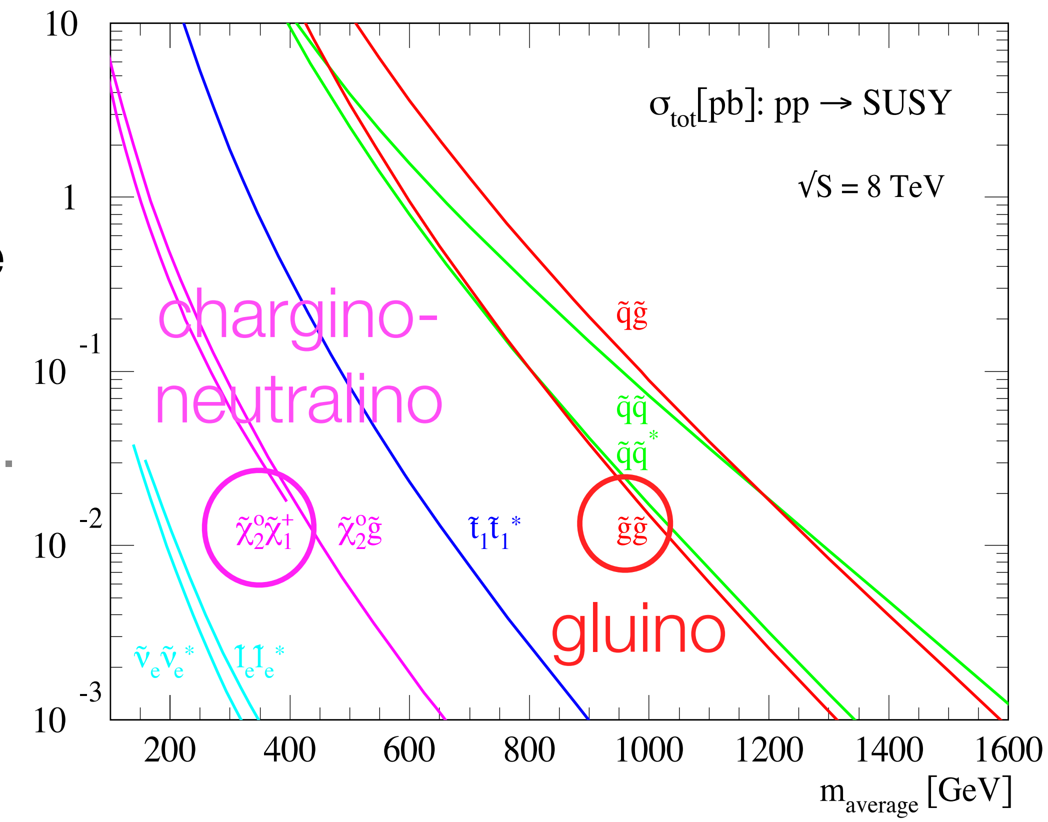
Same sign dilepton events are **very rare in SM** but appear naturally in **new physics**.

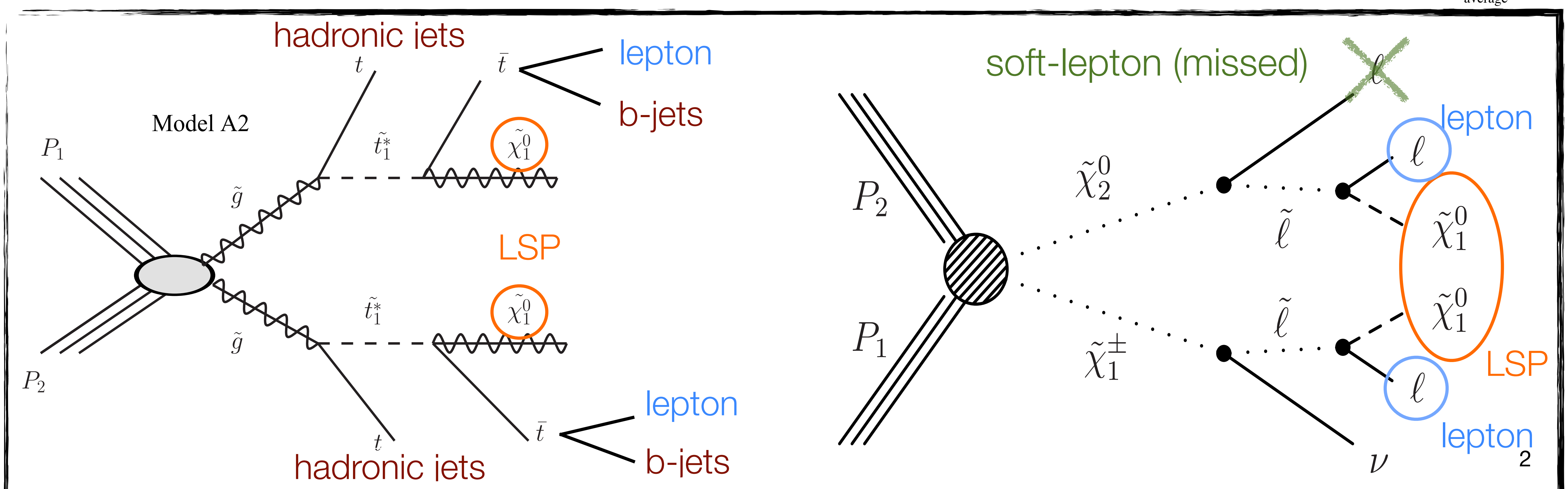
We consider, two possible scenarios. **SUSY processes** are dominated by:

Strong interaction of squarks and gluinos (third-generation).

Electroweak production of charginos and neutralinos (squarks, gluinos are too heavy to play a role in SUSY)

The cascade ends with the LSP (neutral and stable): E_T^{miss}





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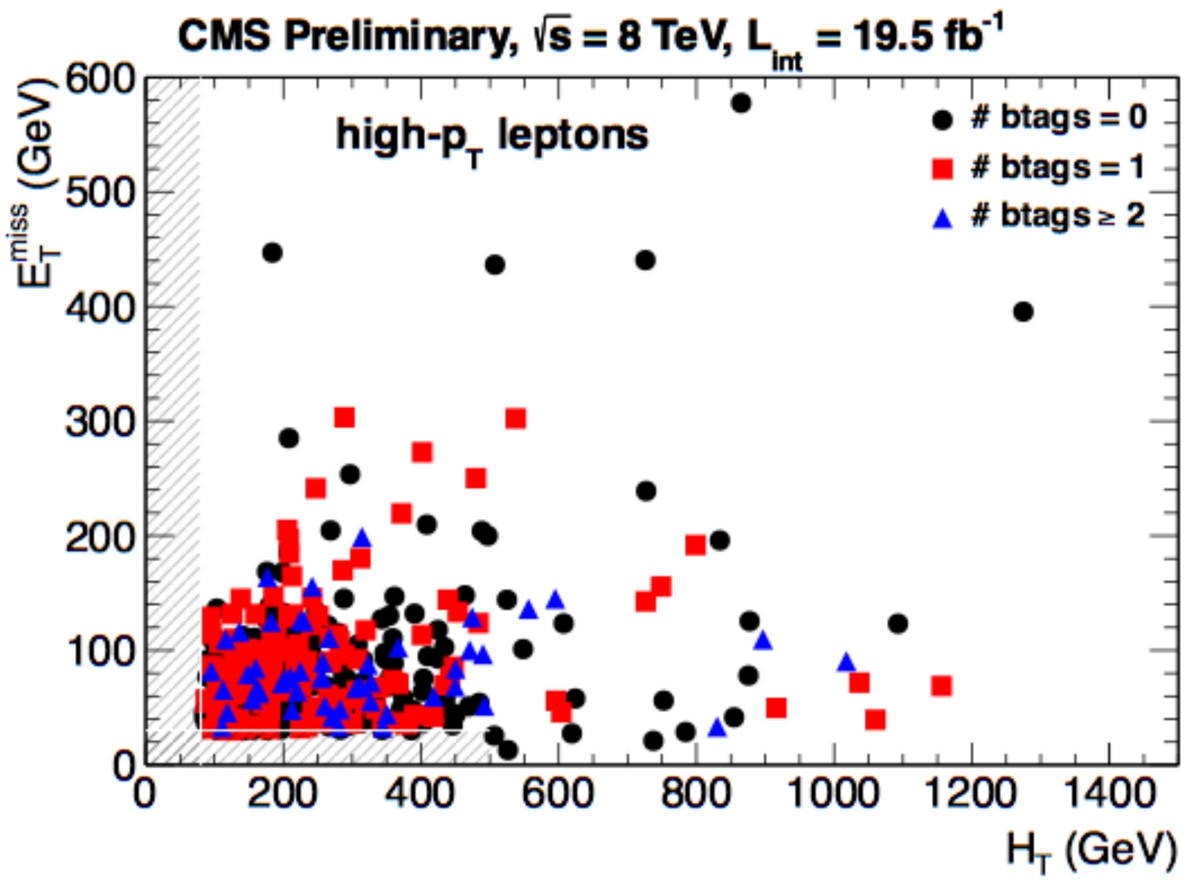
Baseline region for SS+b



Baseline region:

2 same-sign leptons (e,μ) from same vertex.

No third lepton within Z mass (looser)

H_T > 80 GeV, E_T^{miss} > 30 GeV, N_{jets} ≥ 2

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

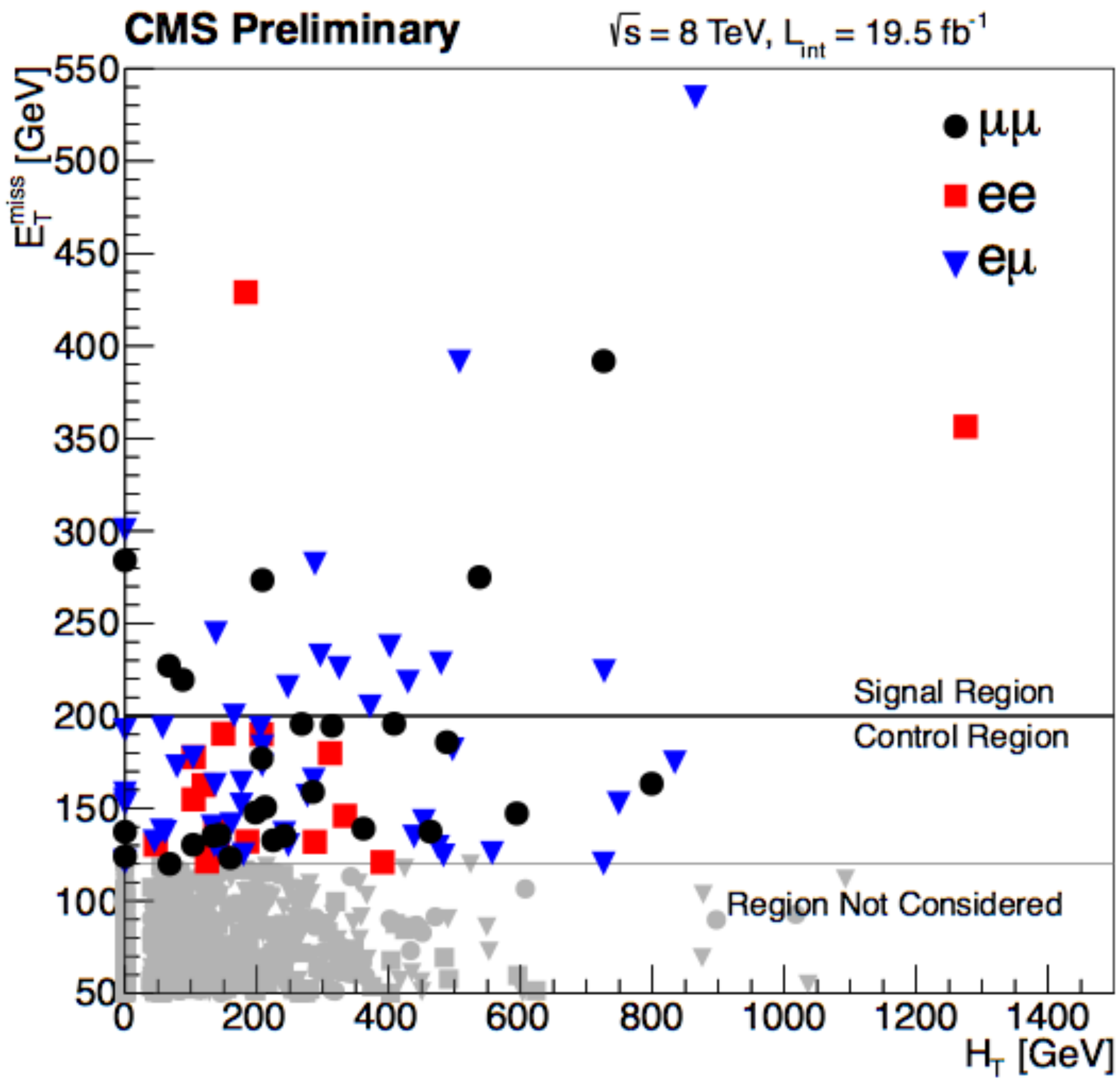
Search regions:

Different cuts on **E_T^{miss}**, **H_T**, and number of **(b)jets** targeting different models

N_{jets}	$N_{b\text{-}jets}$	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++

$N_{b\text{-}jets}$	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

Baseline region for EWKino



Baseline region:

2 same-sign leptons (e,μ) from same vertex.

No third lepton within Z mass (looser)

E_T^{miss} > 120 GeV

We found 94 events on the baseline region.

Search regions:

SR1: $120 < E_T^{miss} < 200$ GeV, $N_{jets} \leq 2$, $N_{b\text{-}jets} = 0$

SR2: $E_T^{miss} > 200$ GeV

SR3: $E_T^{miss} > 120$ GeV, $N_{jets} = 0$

Results will be combined with the 3l analysis (a 3rd lepton veto is applied to be fully exclusive with their selection). Only SR1 and SR2 will be used for interpretation.

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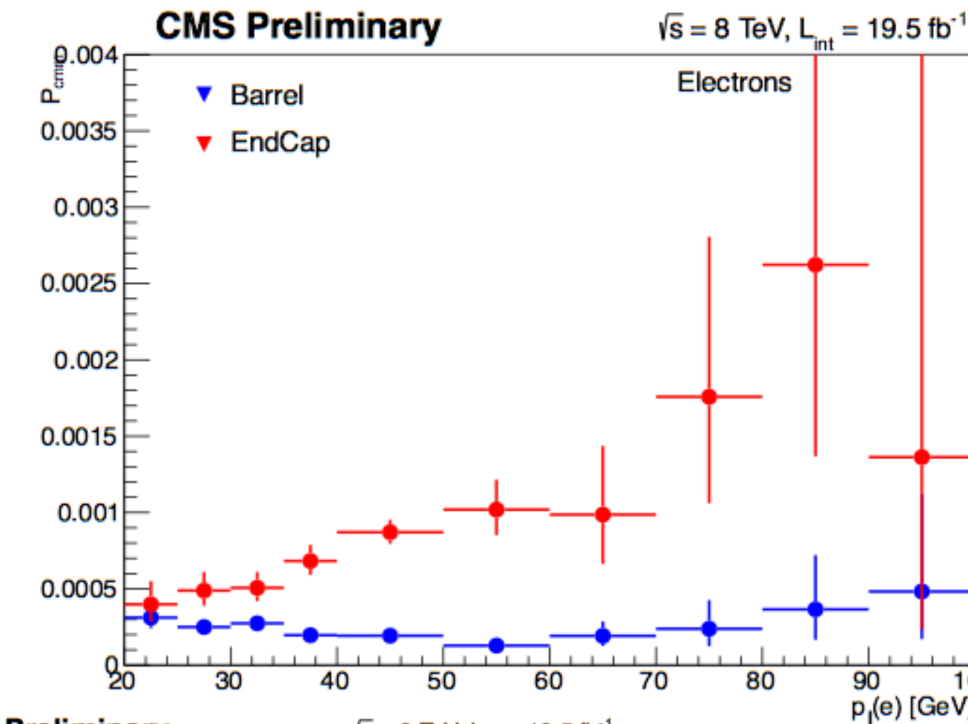
Background estimation

Charge misID (5-10 % of total bkg):

Electrons only. *Data driven*.

Probability measured in Z mass peak using SS and OS leptons in data (MC validated).

$p_{CM} \simeq 0.02\%$ (BB) - 0.2% (EE)



SS+b

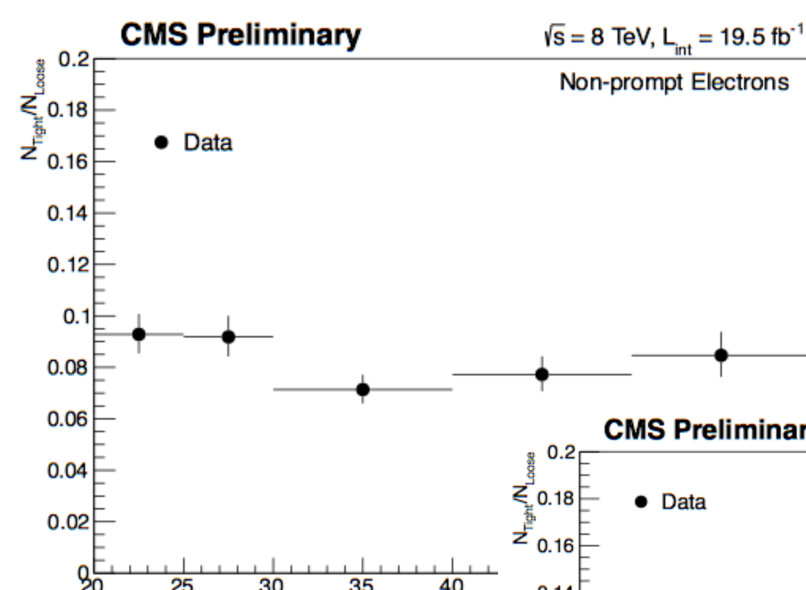
Single and double 'fakes' (10-50% of tot. bkg):

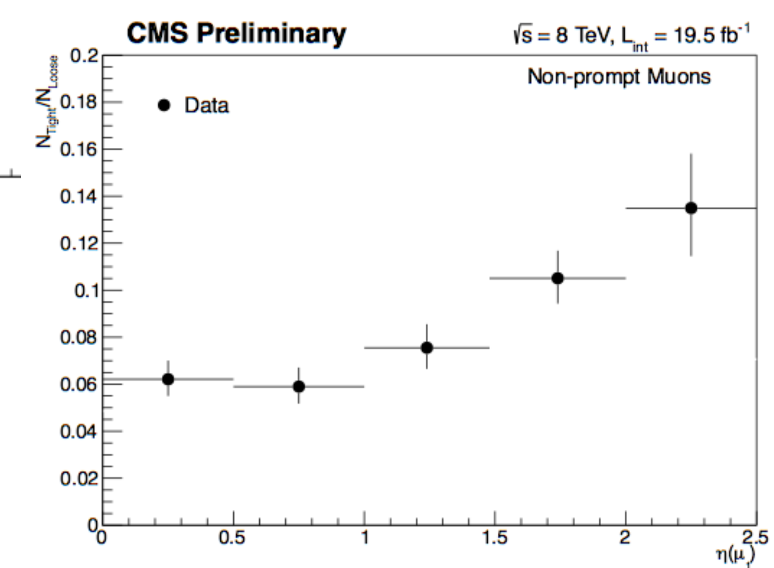
Tight-to-loose method. *Data driven*.

Measure fake/prompt rate in an control region.

Estimate the N_{pf}, N_{ff} from N_{tt}, N_{tl}, N_{ll} in signal region.

50% syst. uncertainty assigned.





Background estimation

EWKino

WZ production (10-50% of tot. bkg):

Madgraph. *MC estimated*.

Validate in WZ enriched region.

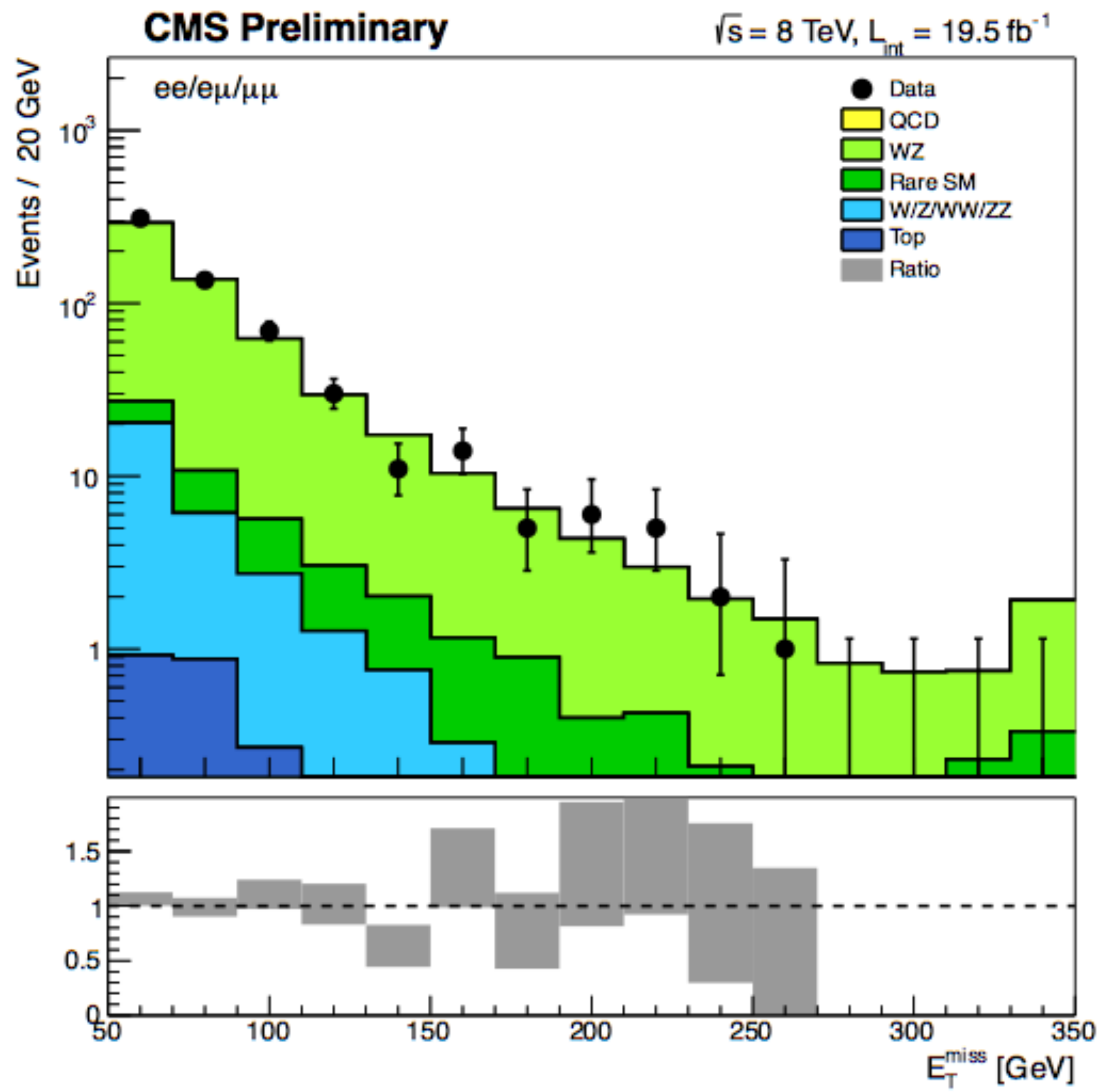
15% syst. uncertainty to account for differences

EWKino / SS+b

Rare SM (20-40% of tot. bkg):

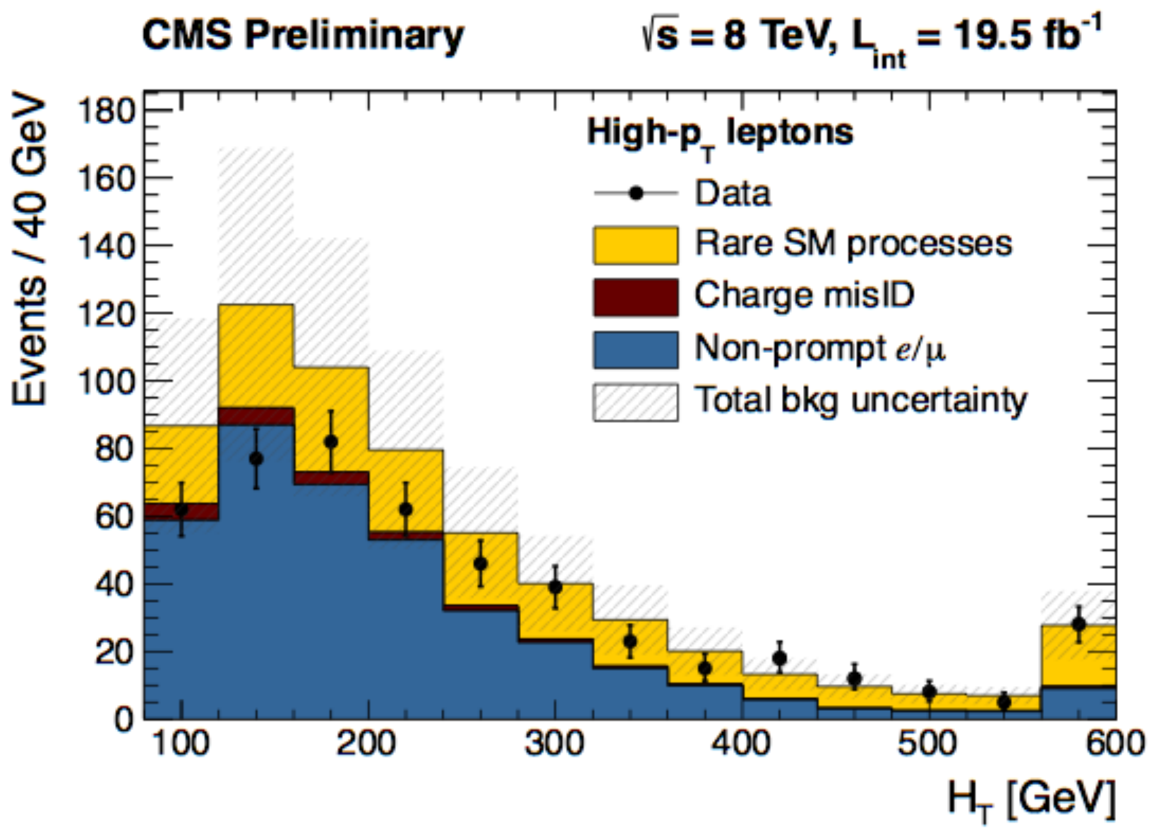
Mainly ttV and $W^{\pm}W^{\pm}$.*MC estimated*

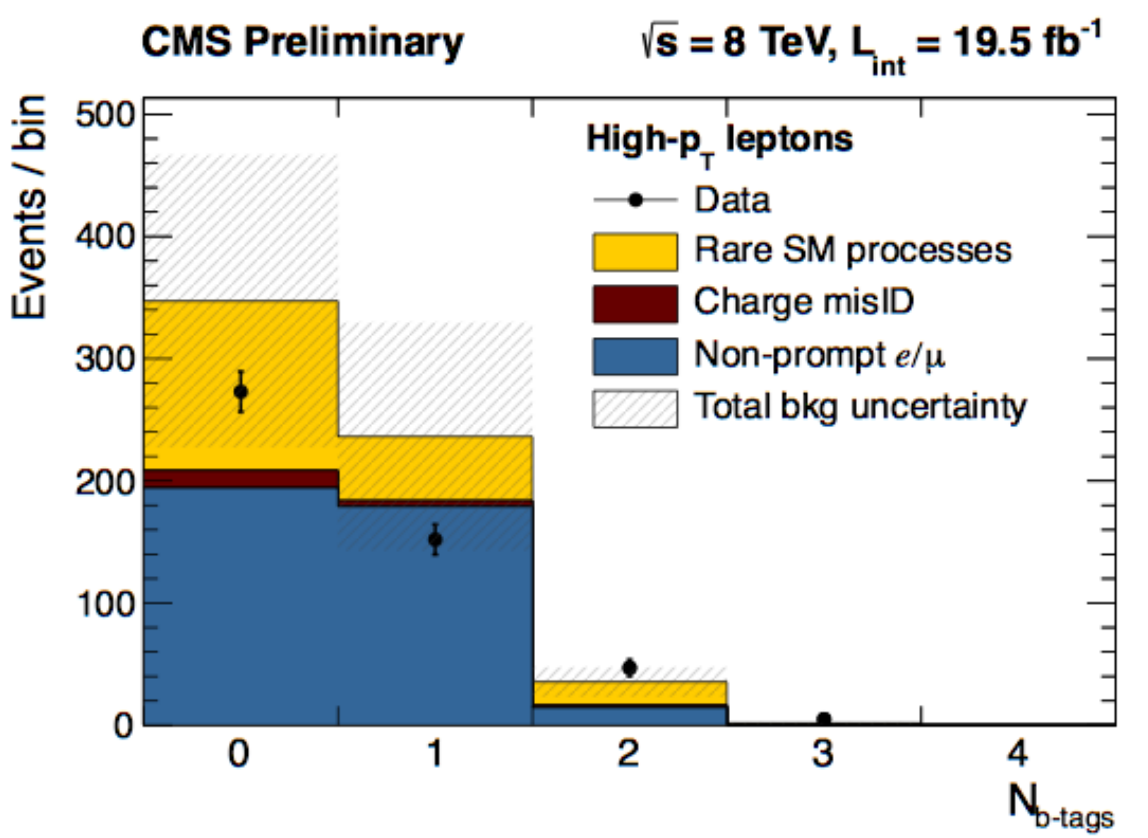
Estimated from MC with 50% syst. uncertainty.



We prove the validity of these method in the baseline region (bkg dominated). Agreement is good so we proceed to the search regions.

Results: SS+b

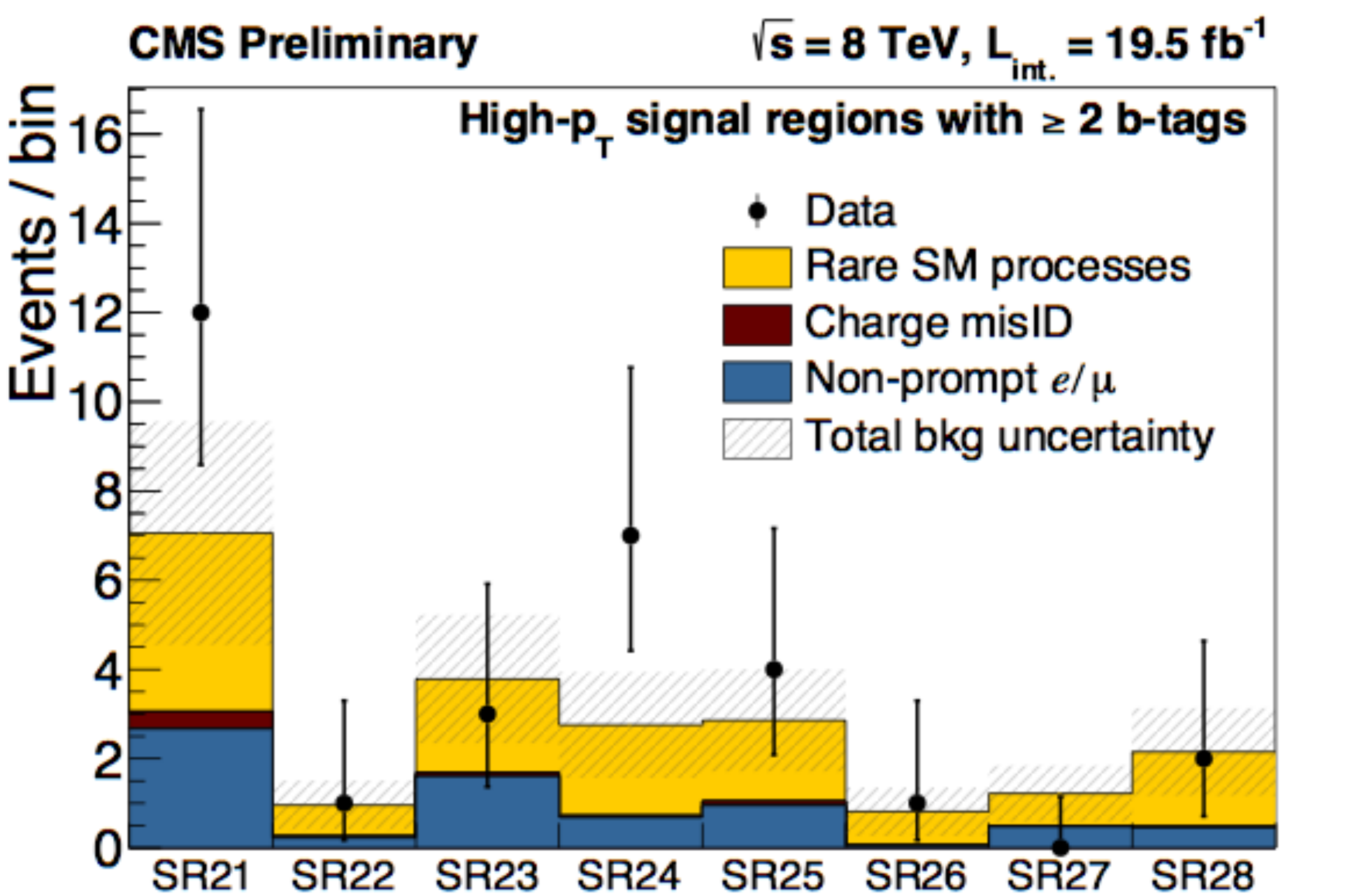




Apply our background estimation methods to each search region.

No excess over SM predictions. SR are exclusive so we use them together in interpretations.

Set exclusion limits on various models.



CMS-PAS-SUS-13-013
to be submitted

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Interpretations: SS+b

Interpret our results in several different models using different regions.

Gluino pair production (decaying to stops or decaying to light quarks), sbottom production, RPV ...

For each model / configuration we will use different signal regions to optimize sensitivity.

Model	Model parameter	Analysis	Signal Regions used
A1		high-p_T	21–28
A2	$m_{\chi_1^0} = 50$ GeV	high-p_T	21–28
B1	$m_{\chi_1^0} = 50$ GeV	high-p_T	11–18, 21–28
B1	$x = m_{\chi_1^0}/m_{\chi_1^\pm} = 0.5$	high-p_T	11–18, 21–28
B1	$x = m_{\chi_1^0}/m_{\chi_1^\pm} = 0.8$	low-p_T	11–18, 21–28
B2	$m_{\chi_1^0} = 50$ GeV, $m_{\chi_1^\pm} = 150$ GeV	high-p_T	21–28
B2	$m_{\chi_1^0} = 50$ GeV, $m_{\chi_1^\pm} = 300$ 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

Systematics are assigned and calculated on a point-by-point basis:

A total sys. uncertainty of ~20% is considered per point.

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

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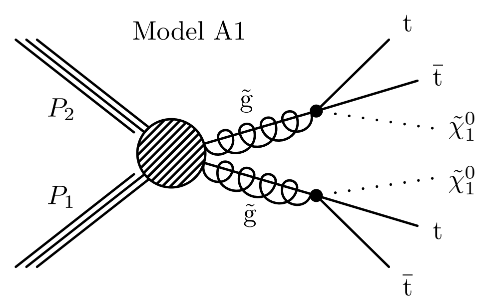
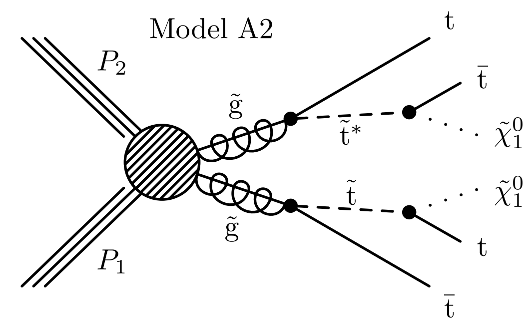
Interpretations: SS+b

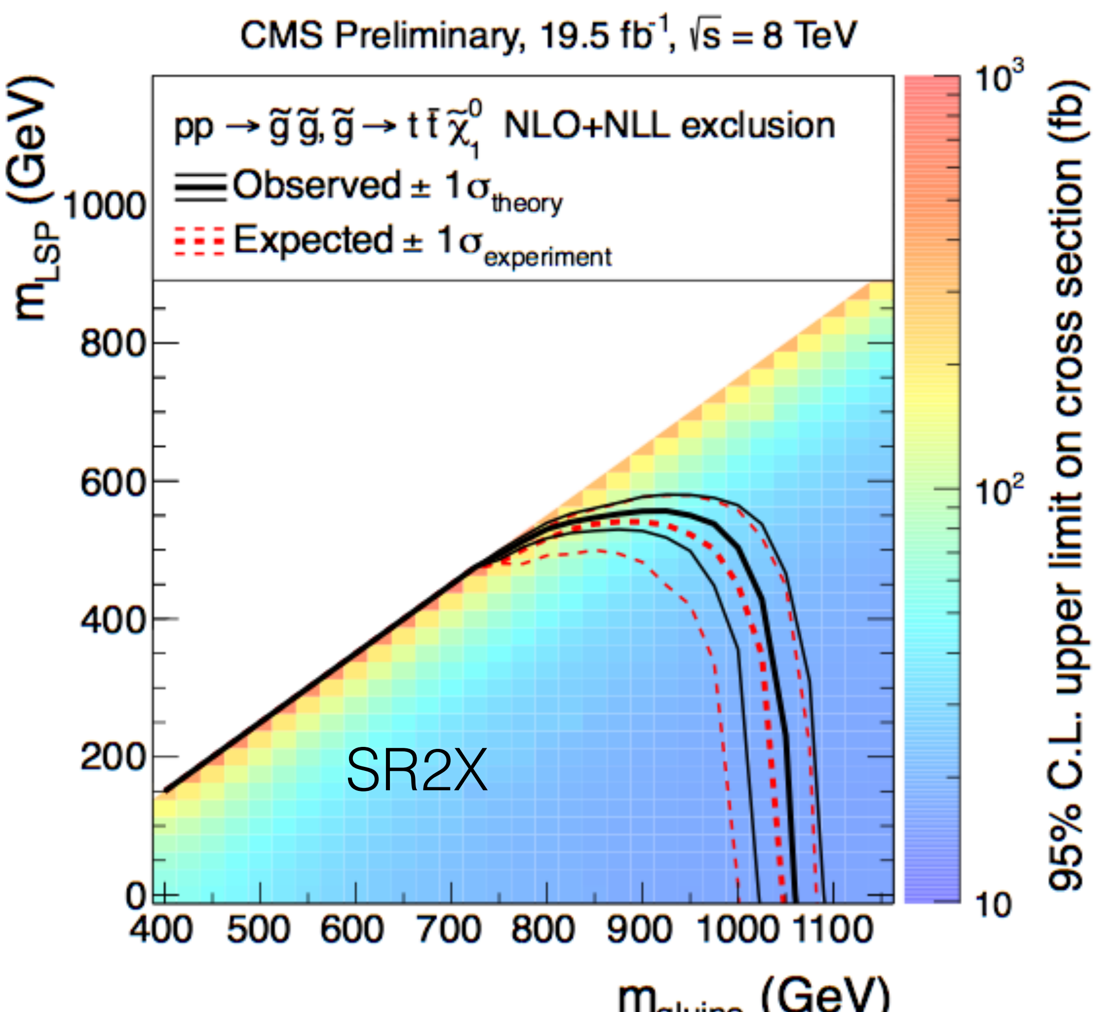
Check documentation for more interpretations.

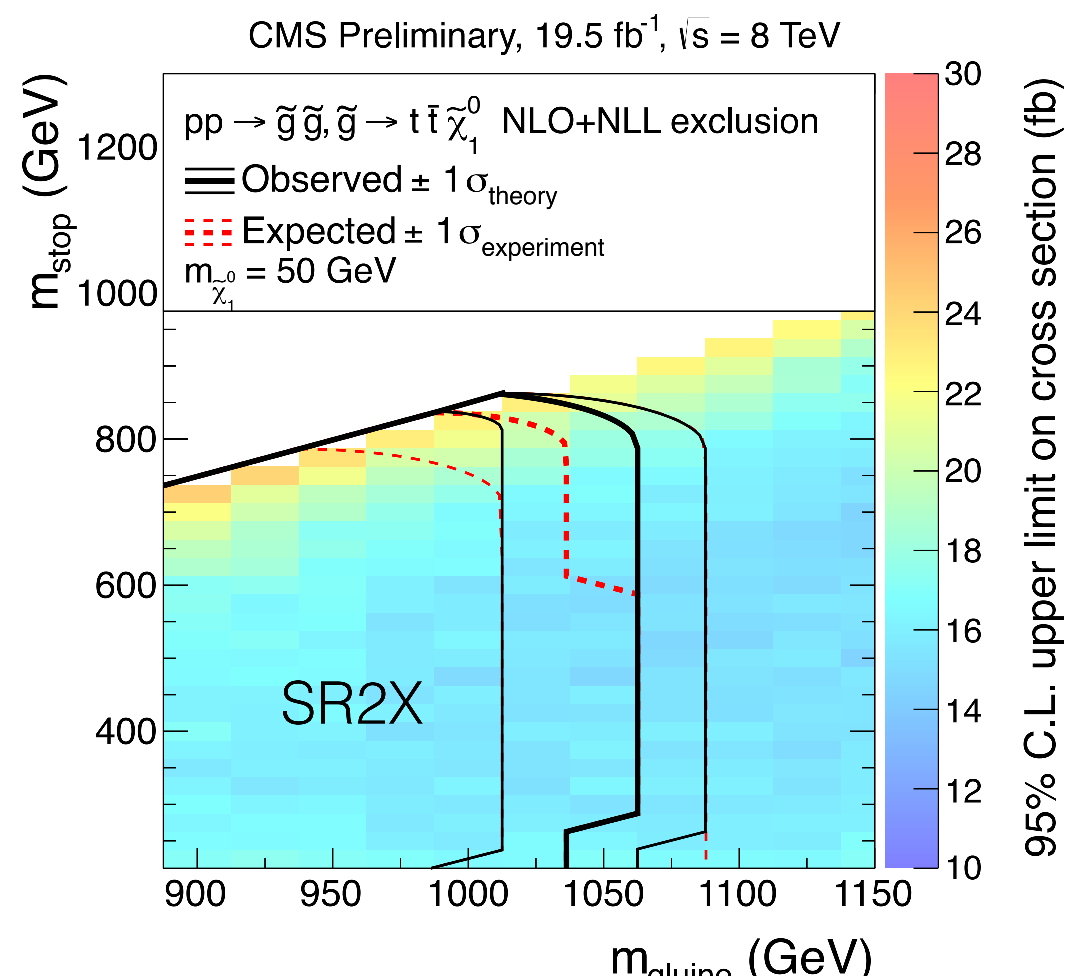
Interpret our results in several different models using different regions.

Three body decay with virtual stops (A1), two-body gluino decay to top-stop pair (A2).





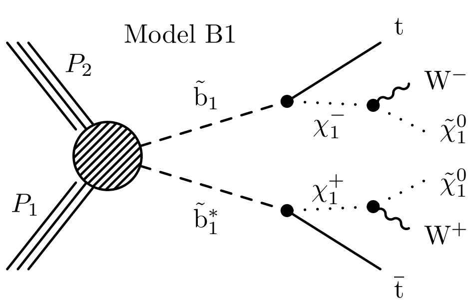


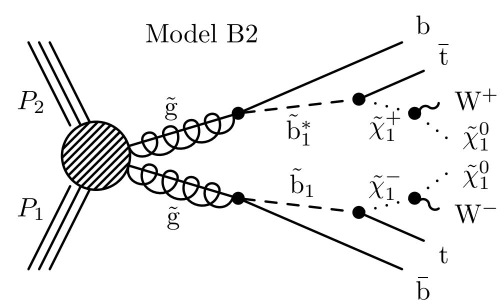


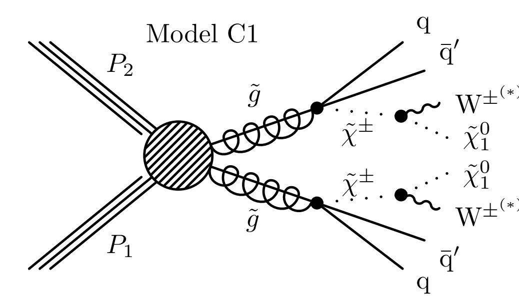
Interpretations: SS+b

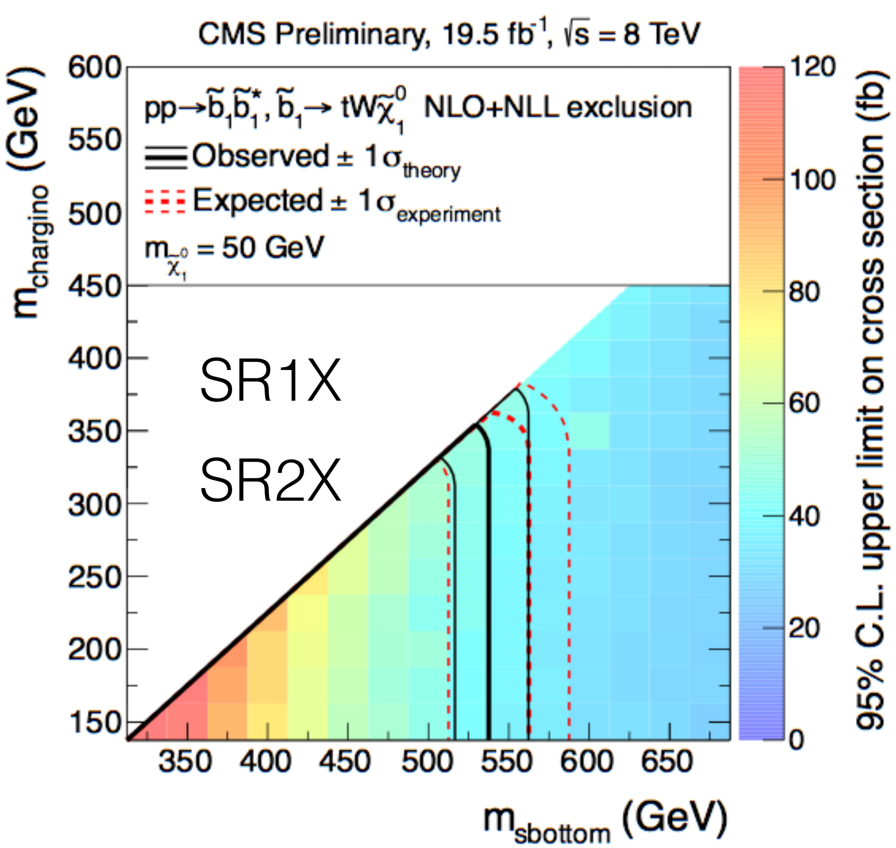
Interpret our results in several different models using different regions.

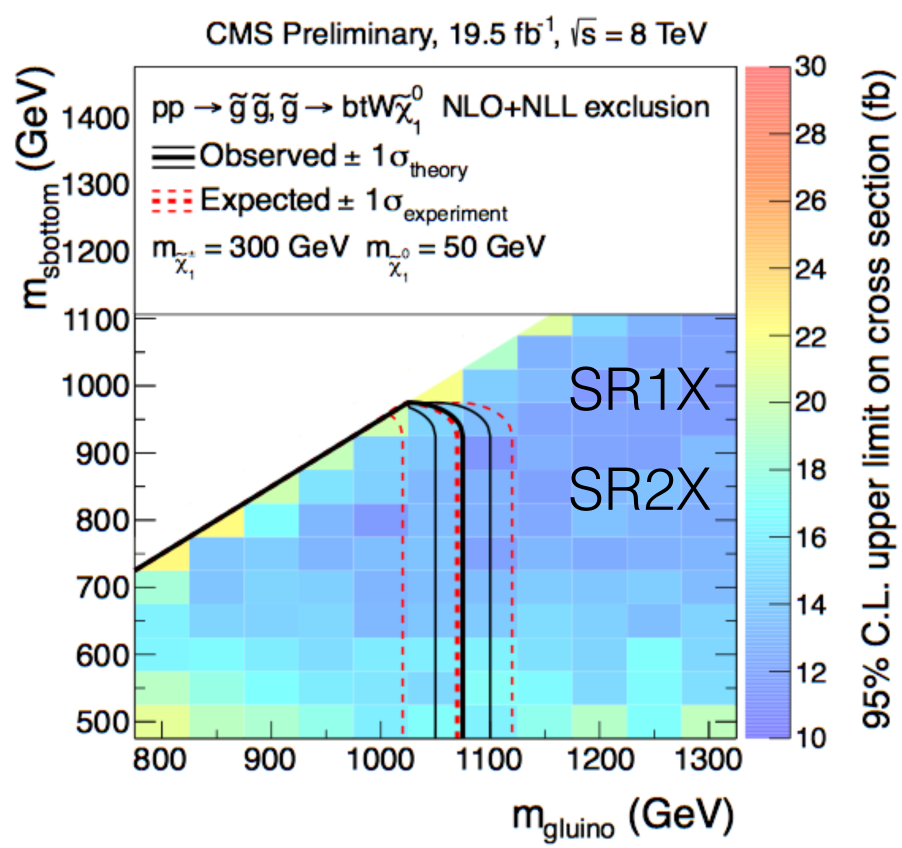
Gluino pair production decaying to sbottoms (B2) or light quarks (C1), direct sbottom pair production (B1).

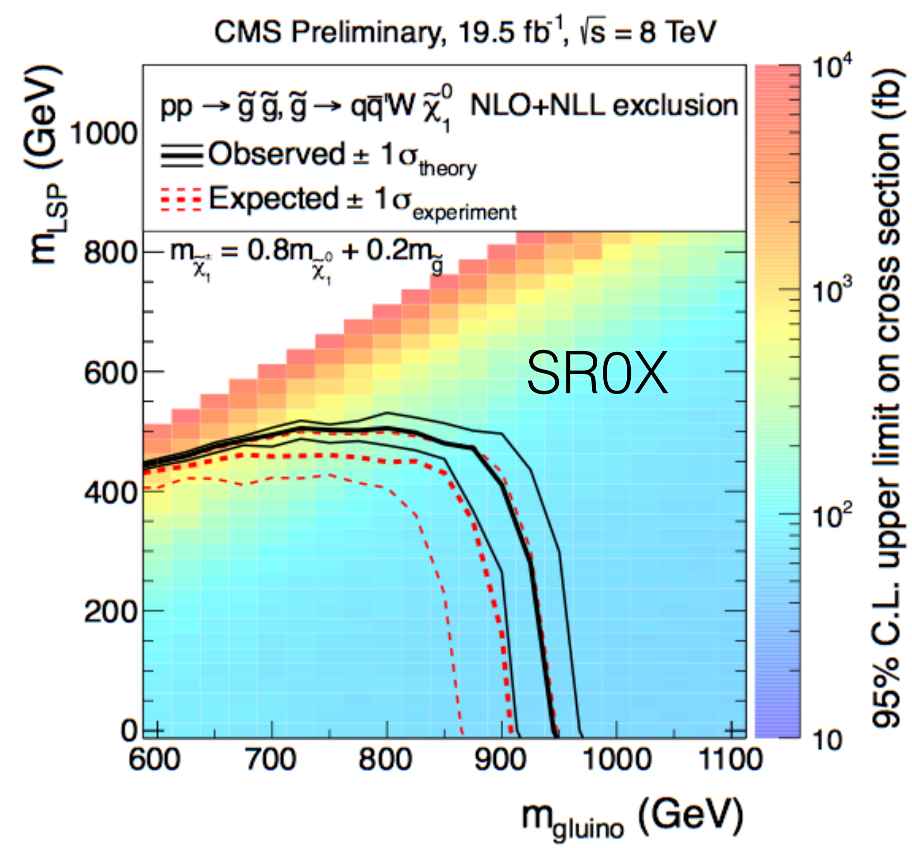












Check documentation for more interpretations.

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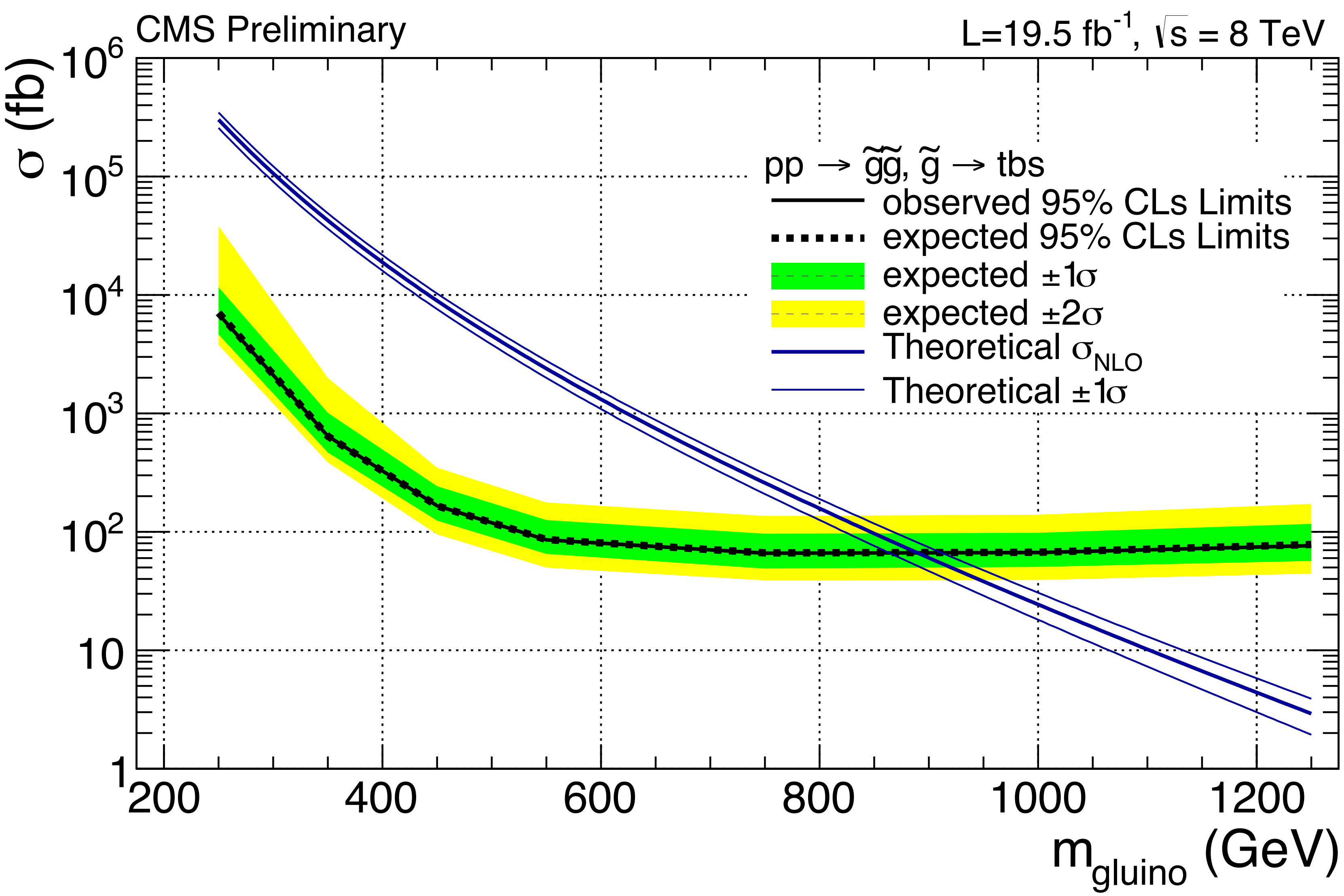
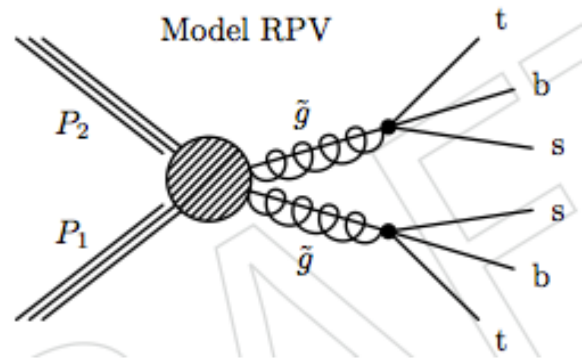
Interpretations: SS+b

Interpret our results in several different models using different regions.

RPV model.





Check documentation for more interpretations.

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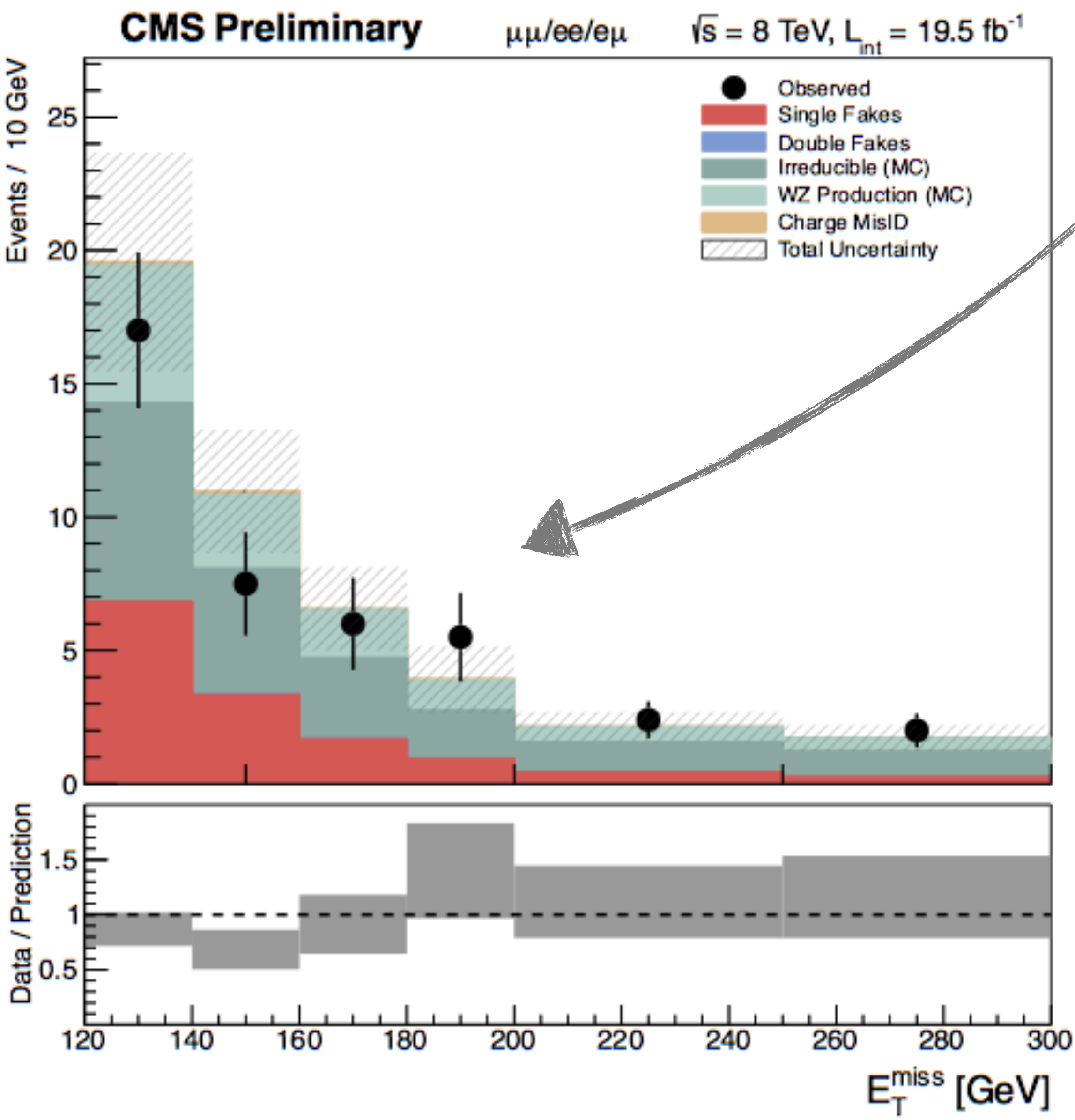
Results: EWK production of $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^{0}$



Apply our background estimation method to our baseline selection. Find good agreement between data / prediction.

Apply the same method to our SR. No excess over the SM prediction.

Set limits on chargino-neutralino production. SR exclusive. Used simultaneously on limit setting.

currently not used for interpretations

	$120< E_T^{miss} <200$ GeV $N_{jets} \leq 2$, $N_{bjets}=0$	$E_T^{miss} >200$ GeV	$120< E_T^{miss} <200$ GeV $N_{jets}=0$	$120< E_T^{miss} <200$ GeV $N_{jets} \leq 2$, $N_{bjets}=0$ 3rd lepton veto	$E_T^{miss} >200$ GeV 3rd lepton veto	$120< E_T^{miss} <200$ GeV $N_{jets}=0$ 3rd lepton veto
Fakes	15.1 ± 7.7	3.4 ± 1.9	4.1 ± 2.2	12.3 ± 6.3	3.1 ± 1.7	3.2 ± 1.7
Charge MisID	0.36 ± 0.02	0.09 ± 0.01	0.08 ± 0.01	0.34 ± 0.02	0.09 ± 0.01	0.07 ± 0.01
Rare SM	15.0 ± 7.8	10.5 ± 5.7	2.4 ± 2.4	11.9 ± 6.3	8.6 ± 4.8	1.4 ± 2.1
WZ	19.4 ± 2.9	5.3 ± 0.8	5.0 ± 0.8	14.3 ± 2.2	3.9 ± 0.6	3.3 ± 0.5
Total Bkg	49.9 ± 11.4	19.4 ± 6.0	11.5 ± 3.3	38.8 ± 9.2	15.6 ± 5.1	7.9 ± 2.8
Data	36	22	8	28	18	4

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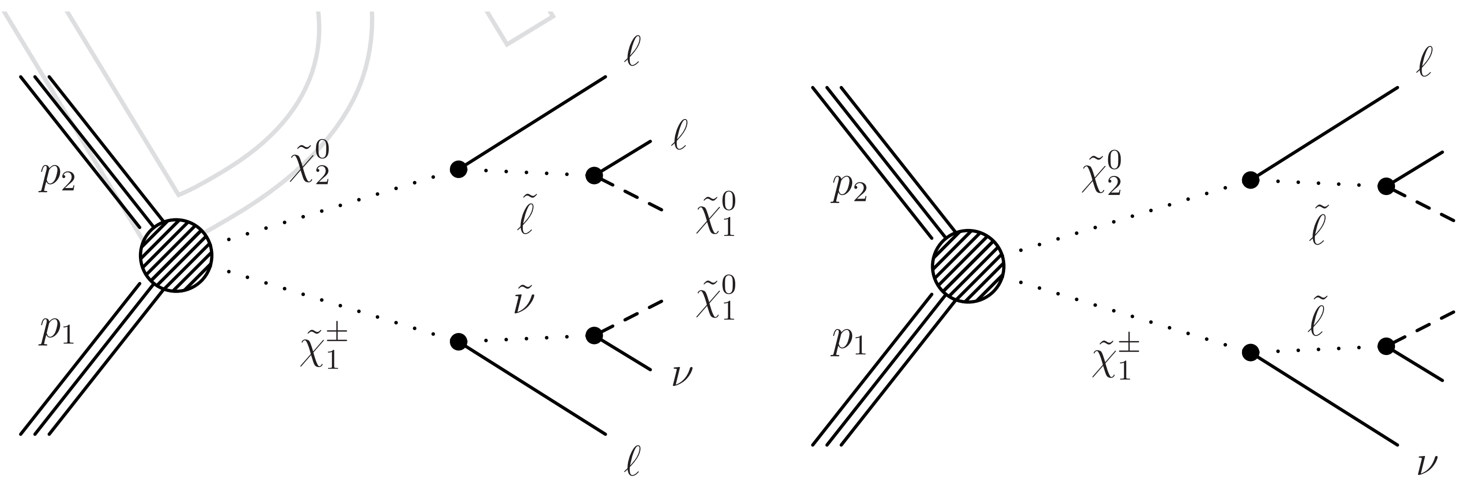
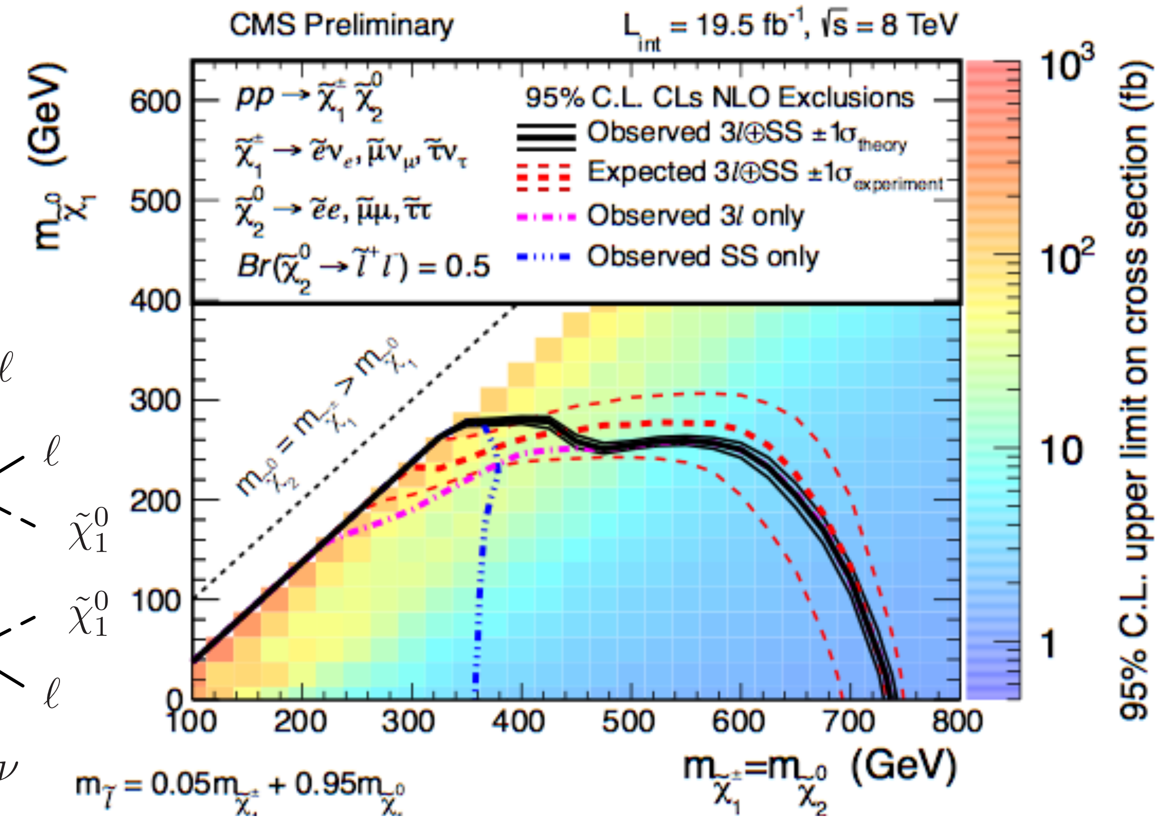
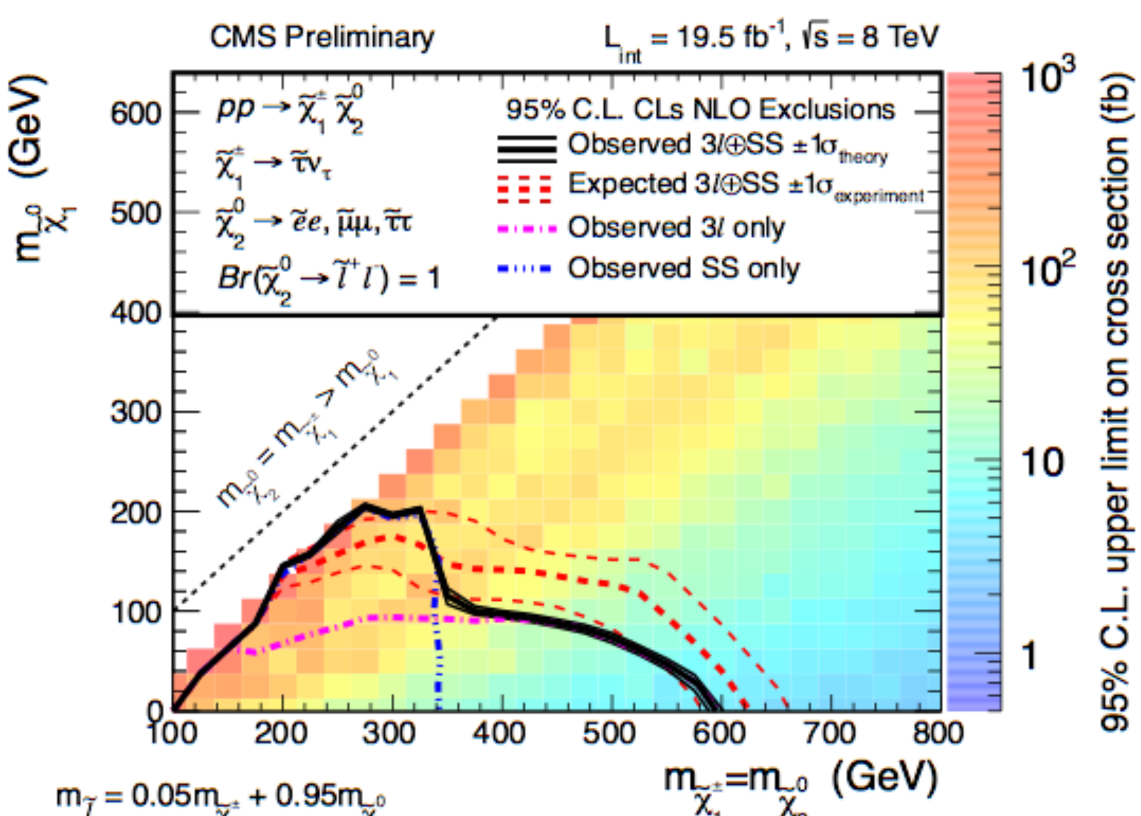
Interpretation: EWK production of $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^{0}$

Combine results with 3l results to set limits. SS lead the exclusion near the diagonal.

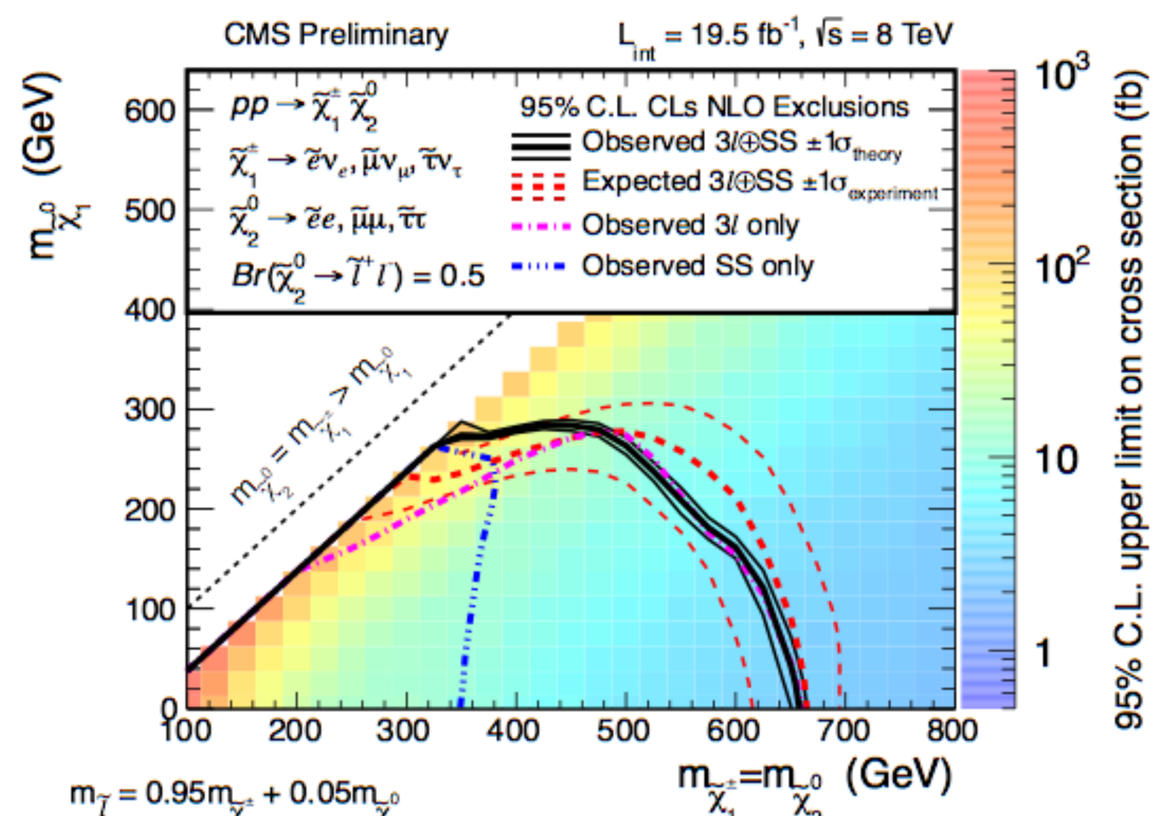




flavor democratic scenario.



τ-enriched scenario.



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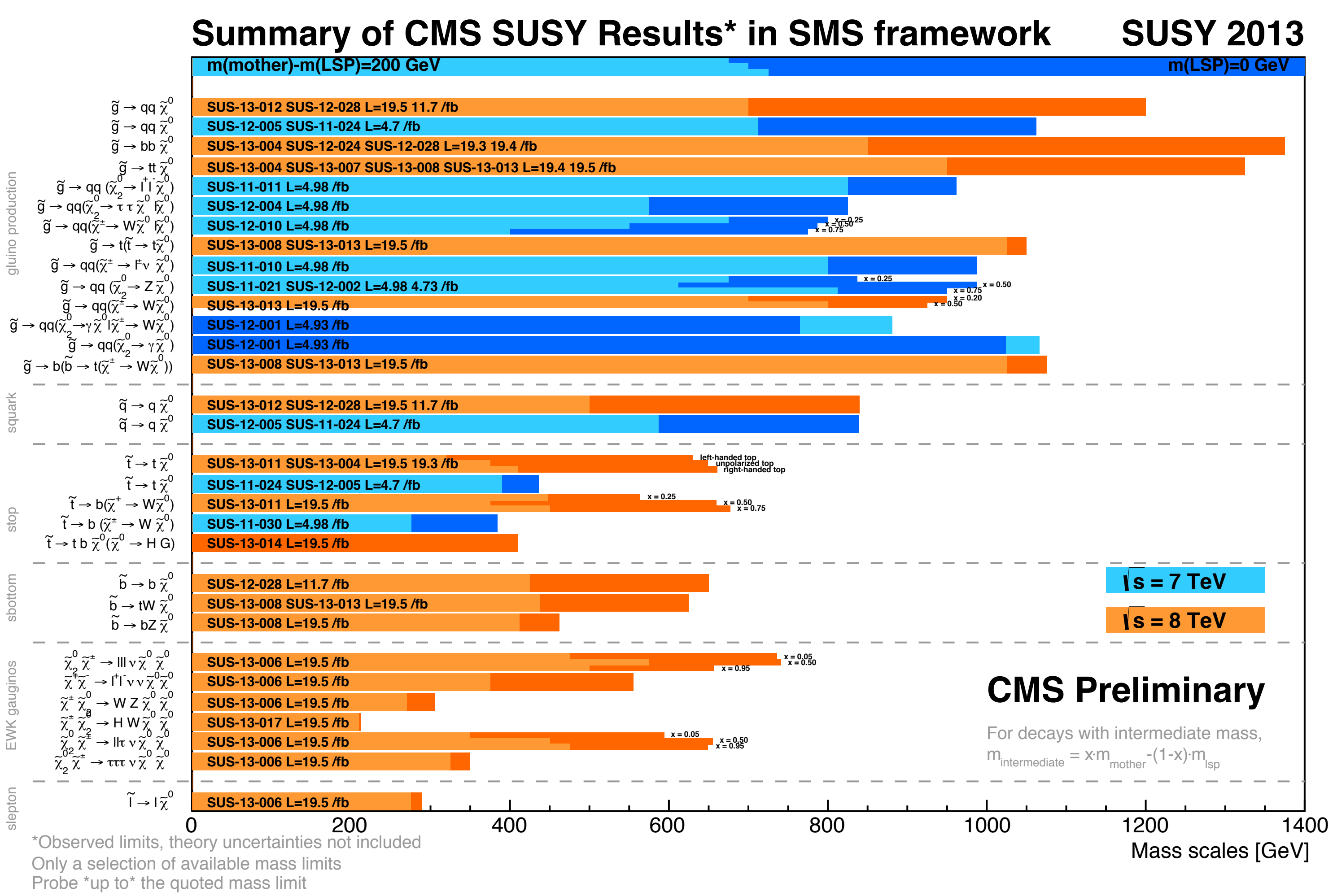
Conclusions

We have searched for new physics in events with two same-sign leptons in the final state using the full 2012 dataset.

Different SR to target different scenarios and models.

Having found no excess over the SM predictions, we interpret our results in various models.



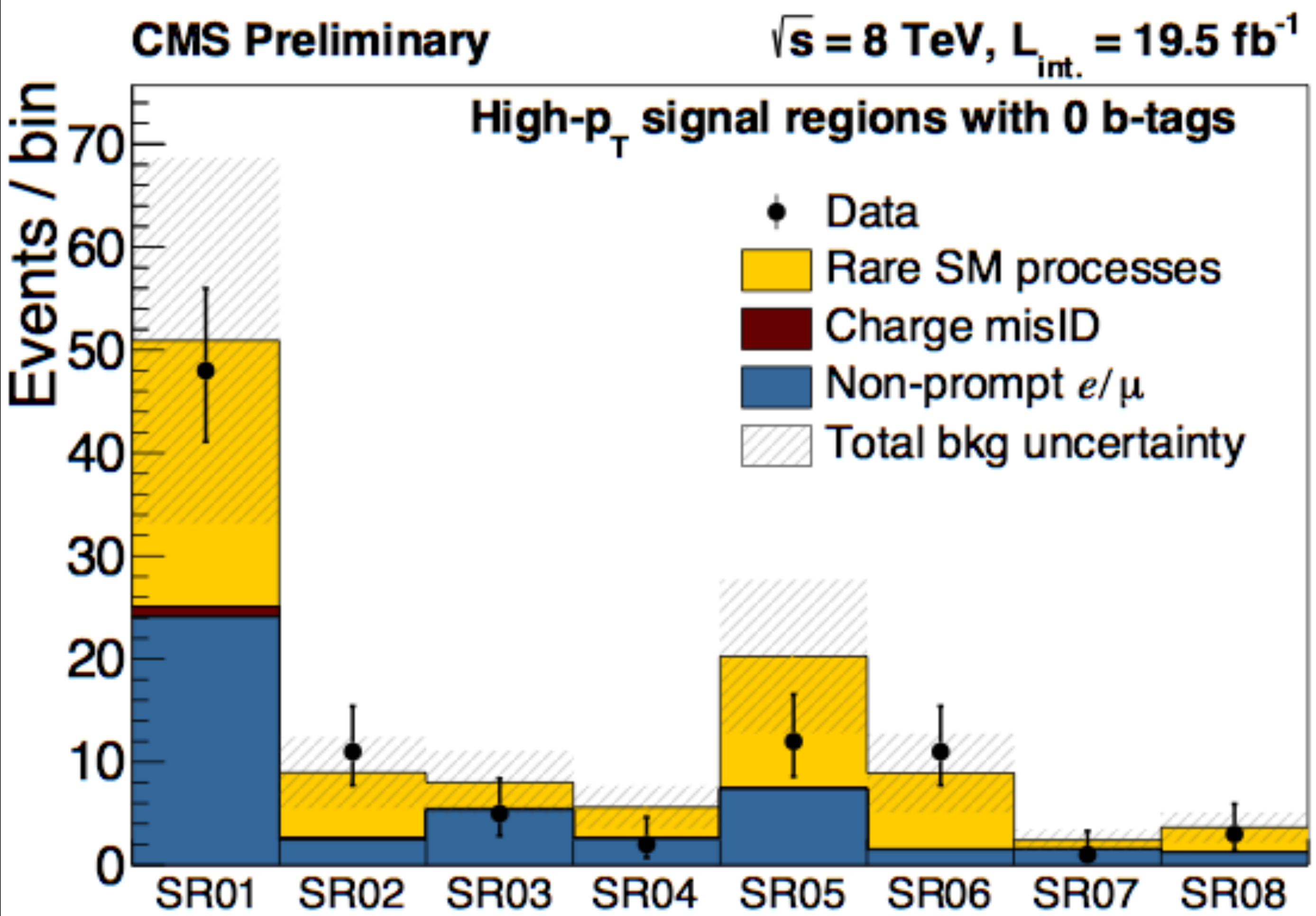
No hints of new physics yet!

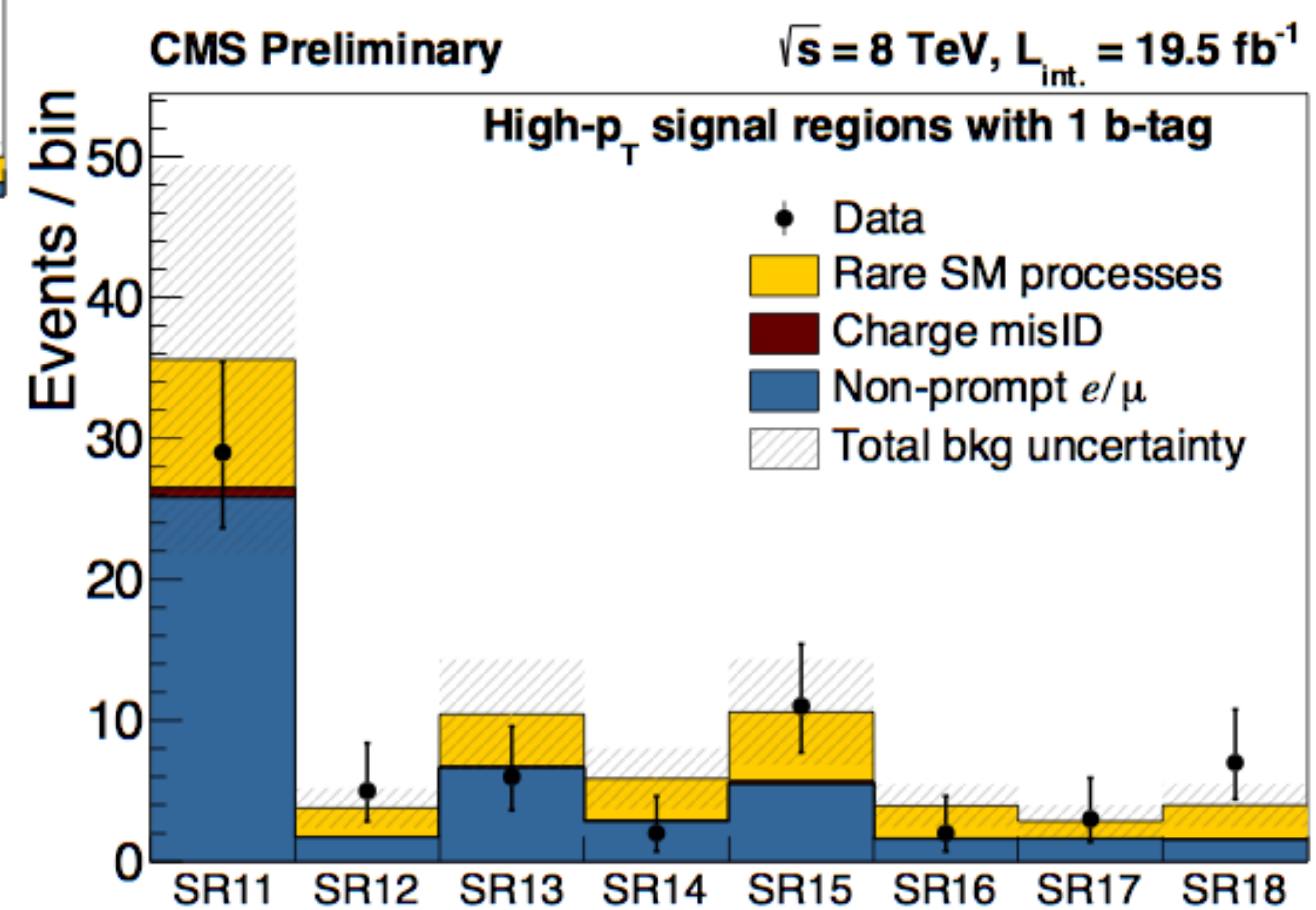
Let's keep our eyes in 2015.
Very exciting new physics may show up at the higher energy run.

Thank you for your attention!

Thank you!

Prediction / observed in SR





SR yields and predictions

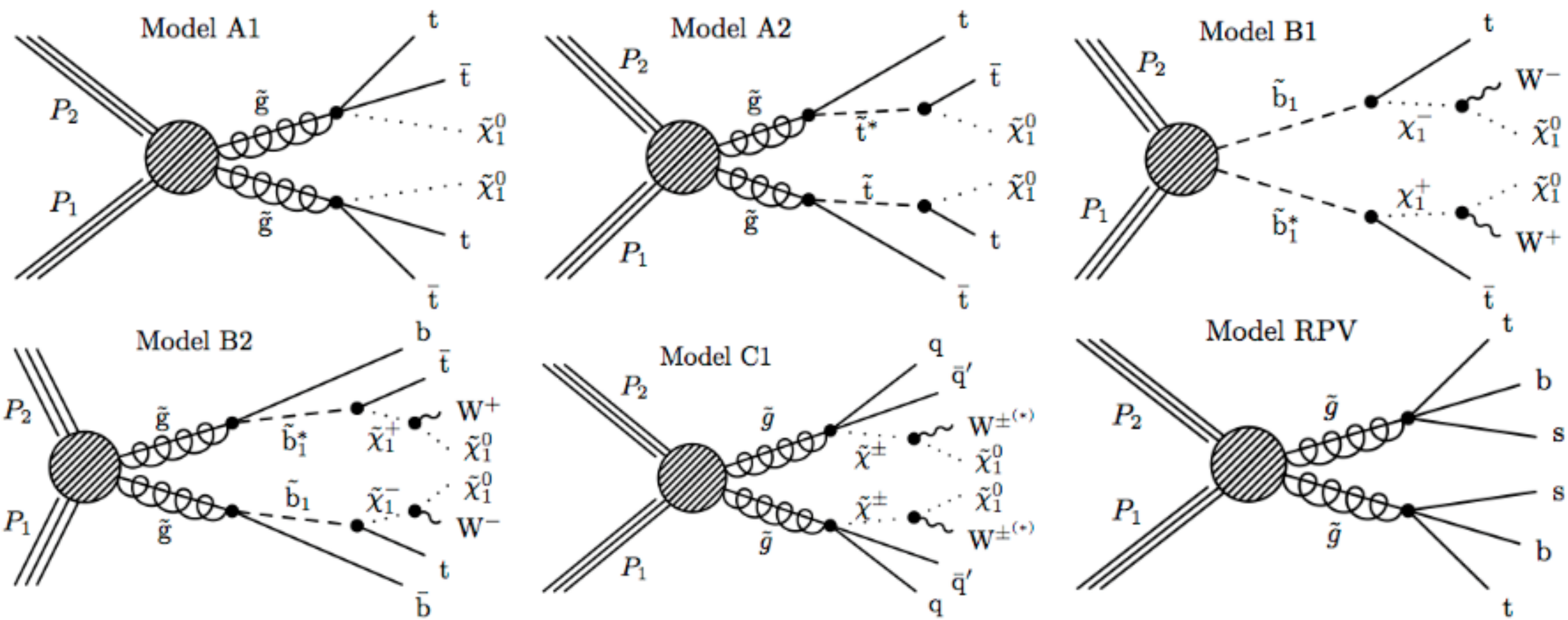
SR	low-p_T Expected			low-p_T Observed	high-p_T Expected			high-p_T Observed
1	44	±	16	50	51	±	18	48
2	12	±	4	17	9.0	±	3.5	11
3	12	±	5	13	8.0	±	3.1	5
4	9.1	±	3.4	4	5.6	±	2.1	2
5	21	±	8	22	20	±	7	12
6	13	±	5	18	9	±	4	11
7	3.5	±	1.4	2	2.4	±	1.0	1
8	5.8	±	2.1	4	3.6	±	1.5	3
11	32	±	13	40	36	±	14	29
12	6.0	±	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

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

Signal systematics

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

Models used for interpretation

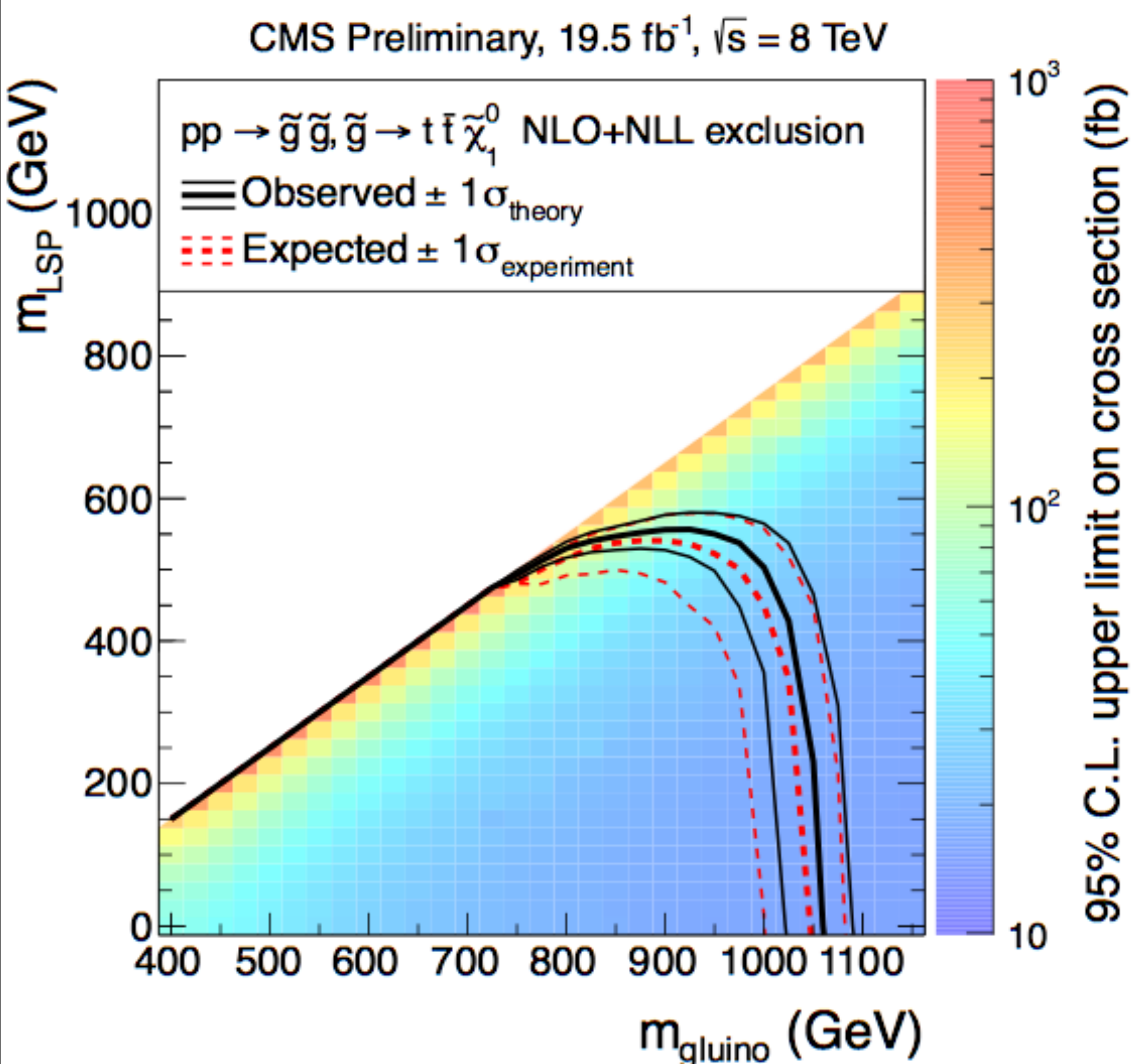


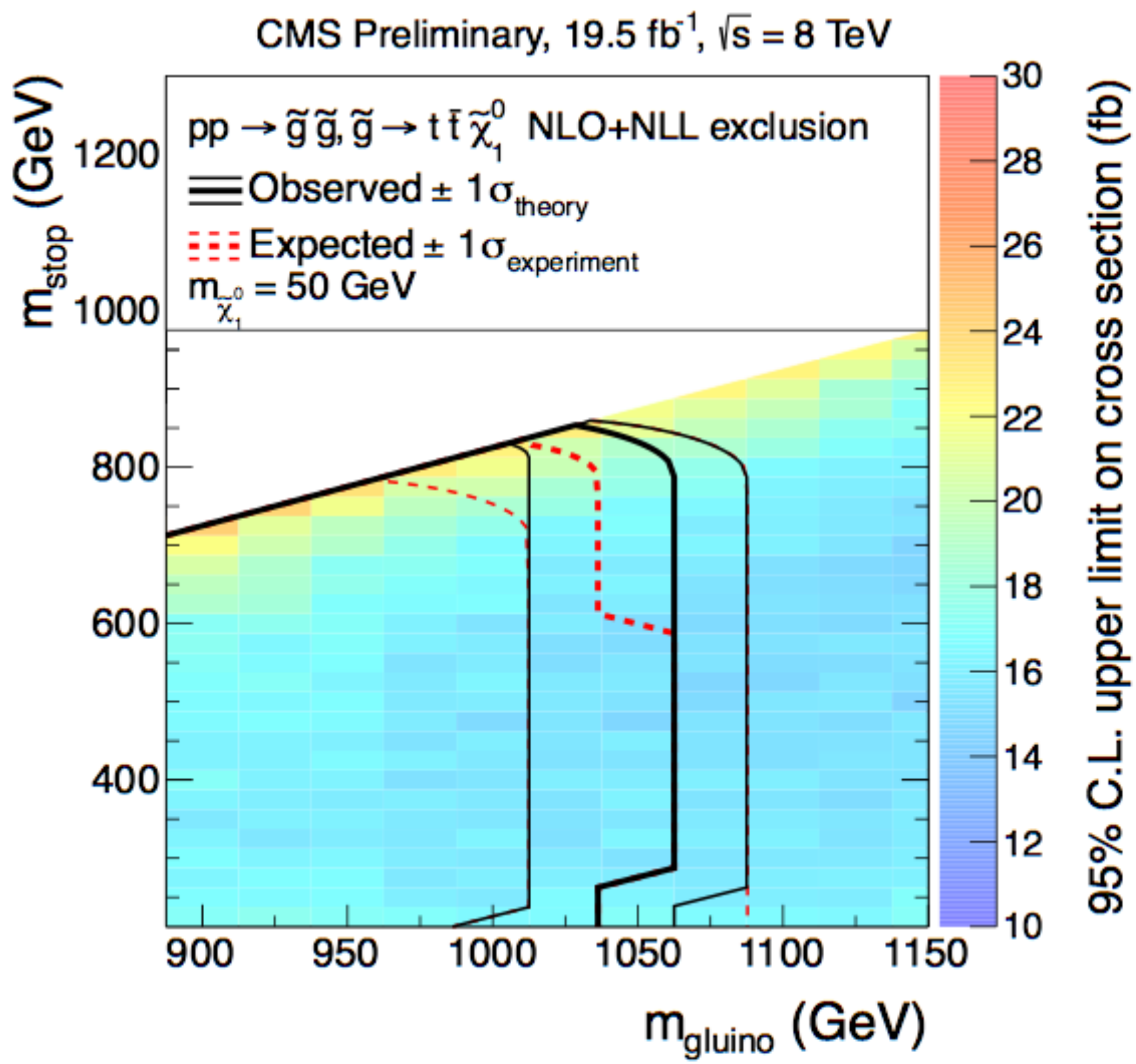
SR used for which model.

Model	Model parameter	Analysis	Signal Regions used
A1		high-p_{T}	21–28
A2	$\mathrm{m}_{\chi_1^0} = 50$ GeV	high-p_{T}	21–28
B1	$\mathrm{m}_{\chi_1^0} = 50$ GeV	high-p_{T}	11–18, 21–28
B1	$\mathrm{x} = \mathrm{m}_{\chi_1^0}/\mathrm{m}_{\chi_1^\pm} = 0.5$	high-p_{T}	11–18, 21–28
B1	$\mathrm{x} = \mathrm{m}_{\chi_1^0}/\mathrm{m}_{\chi_1^\pm} = 0.8$	low-p_{T}	11–18, 21–28
B2	$\mathrm{m}_{\chi_1^0} = 50$ GeV, $\mathrm{m}_{\chi_1^\pm} = 150$ GeV	high-p_{T}	21–28
B2	$\mathrm{m}_{\chi_1^0} = 50$ GeV, $\mathrm{m}_{\chi_1^\pm} = 300$ GeV	high-p_{T}	21–28
C1	$\mathrm{x} = 0.5$	high-p_{T}	01–08
C1	$\mathrm{x} = 0.8$	low-p_{T}	01–08
RPV		high-p_{T}	RPV2
$\mathrm{pp} \rightarrow \mathrm{tt} + \bar{\mathrm{t}}\bar{\mathrm{t}}$		high-p_{T}	SStop1, SStop2
$\mathrm{pp} \rightarrow \mathrm{tt}$		high-p_{T}	SStop1++, SStop2++
$\mathrm{pp} \rightarrow \mathrm{tt}\bar{\mathrm{t}}\bar{\mathrm{t}}$		high-p_{T}	21–28

Interpretation: model A1 and A2

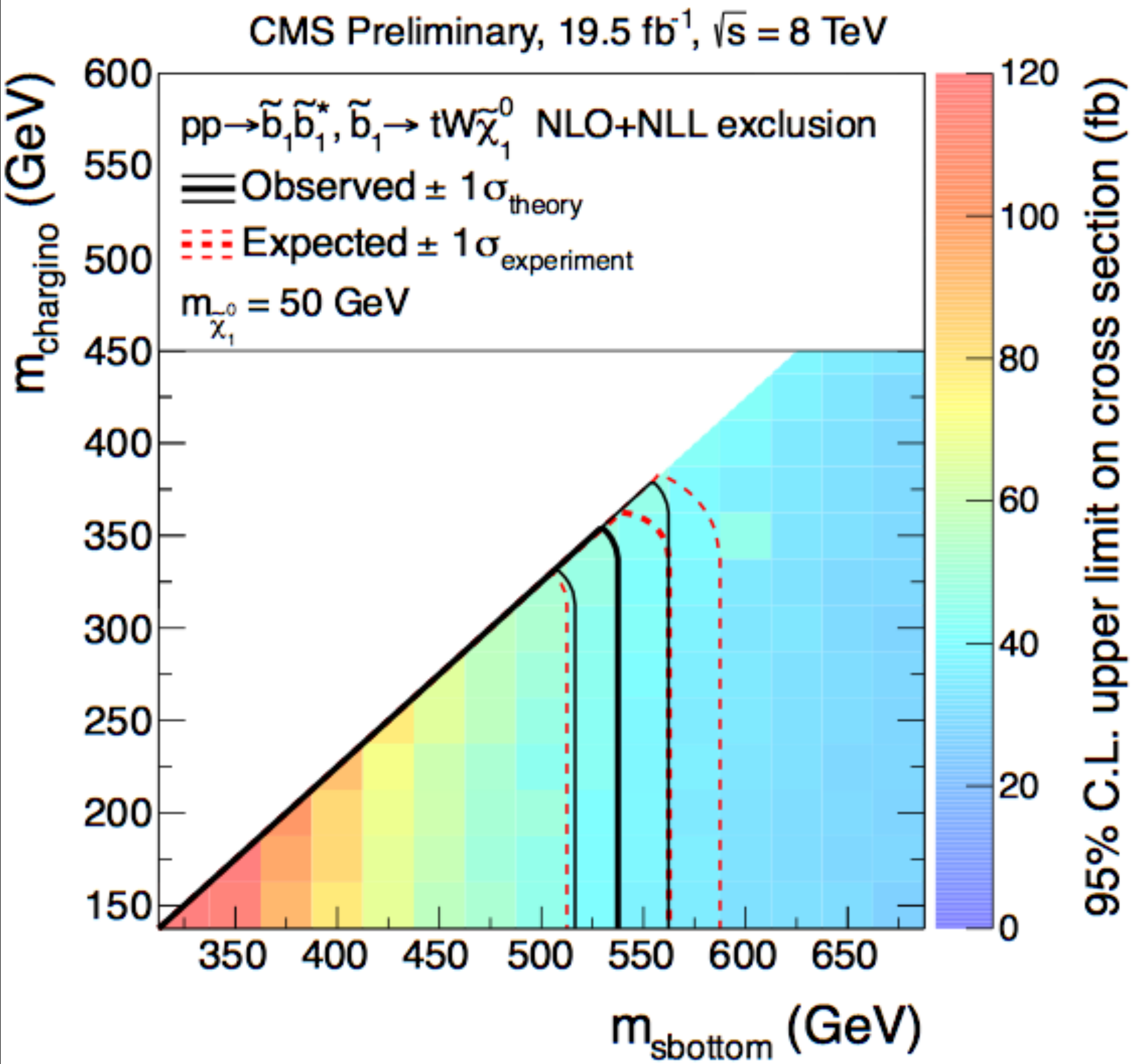
Gluino pair production. A1 gluino undergoes a three-body decay with the stop off-shell. A2, gluino decays to top and stop.

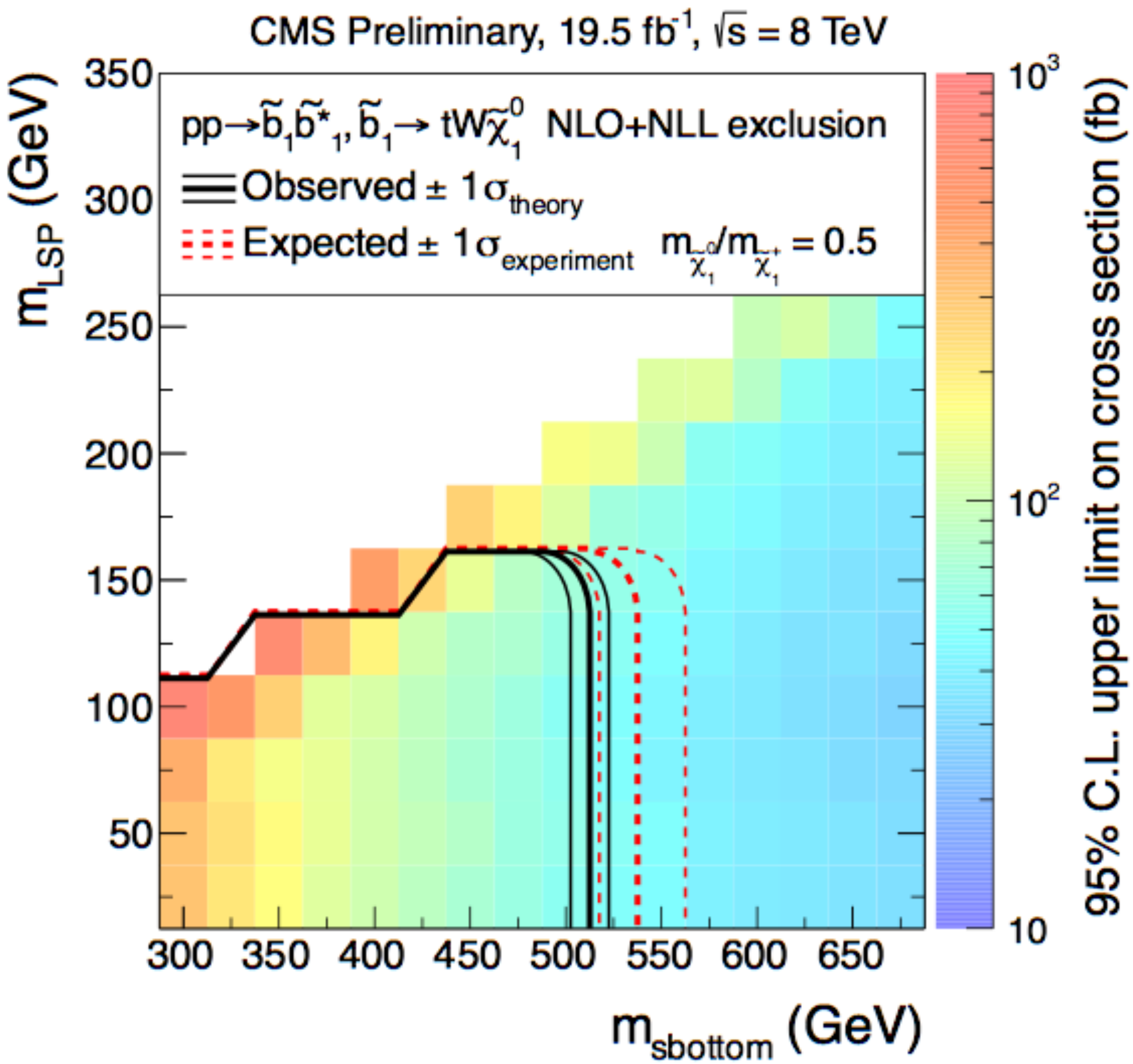




Interpretation: model B1

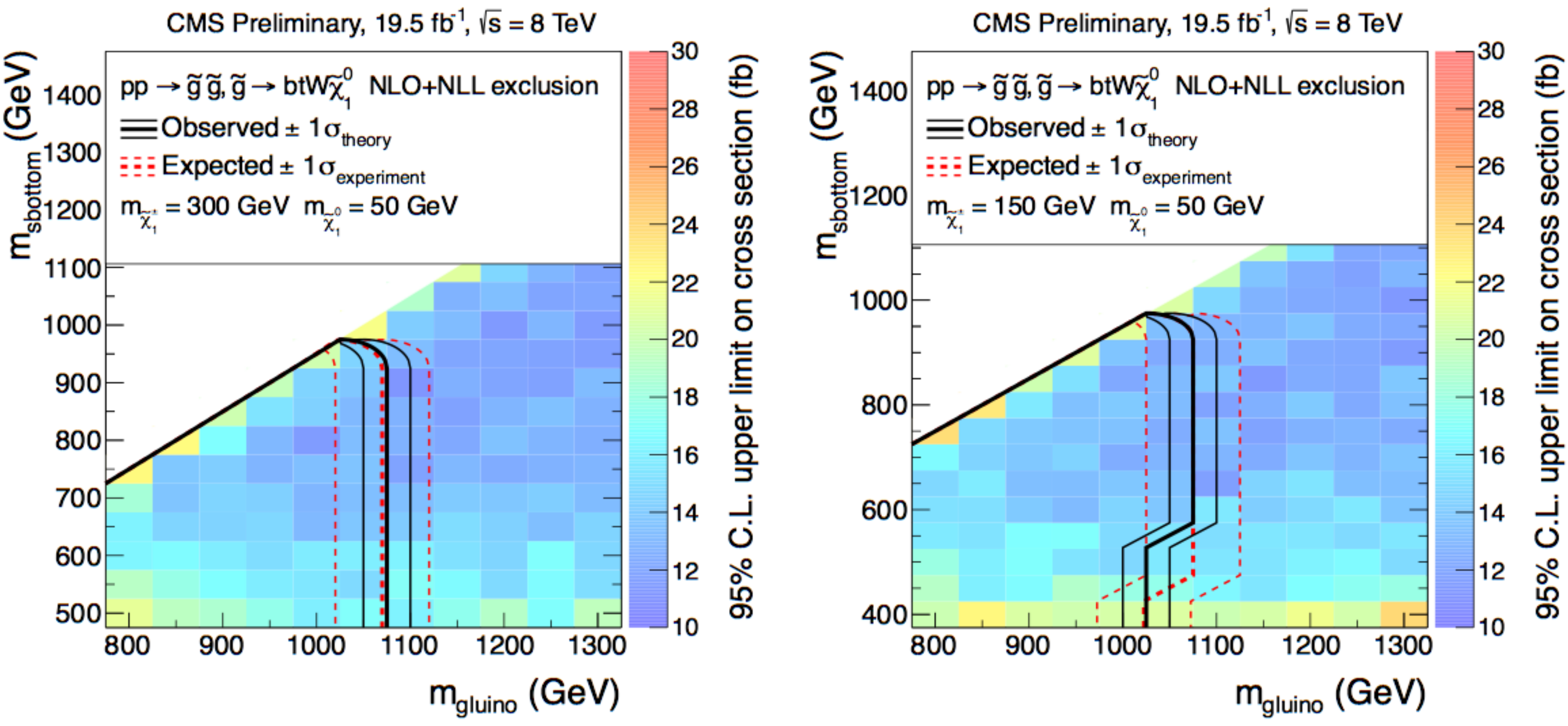
Sbottom pair production. sbottom decays to top, chargino. Fixed LSP mass (left), and LSP mass is half the chargino mass.





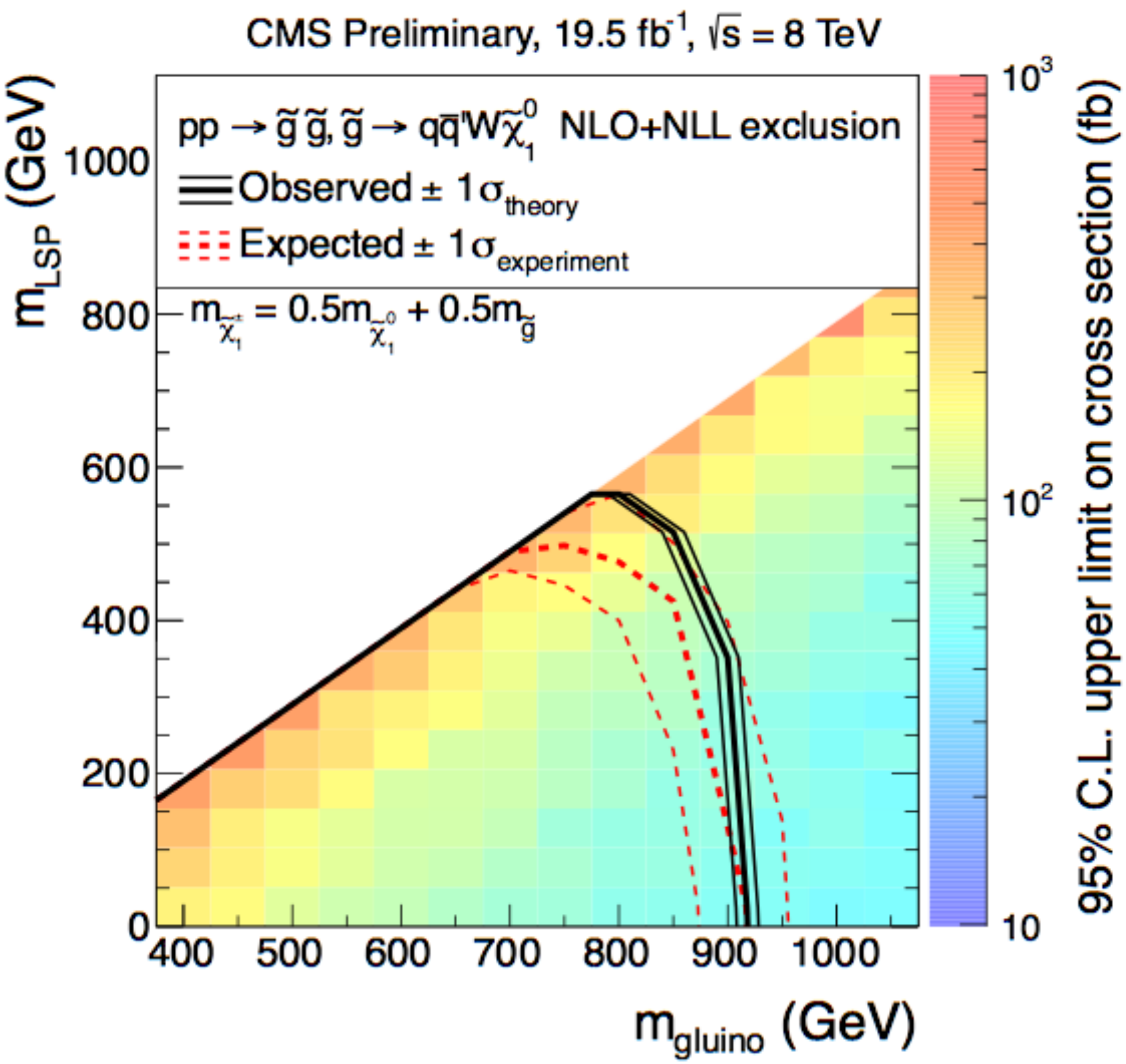
Interpretation: model B2

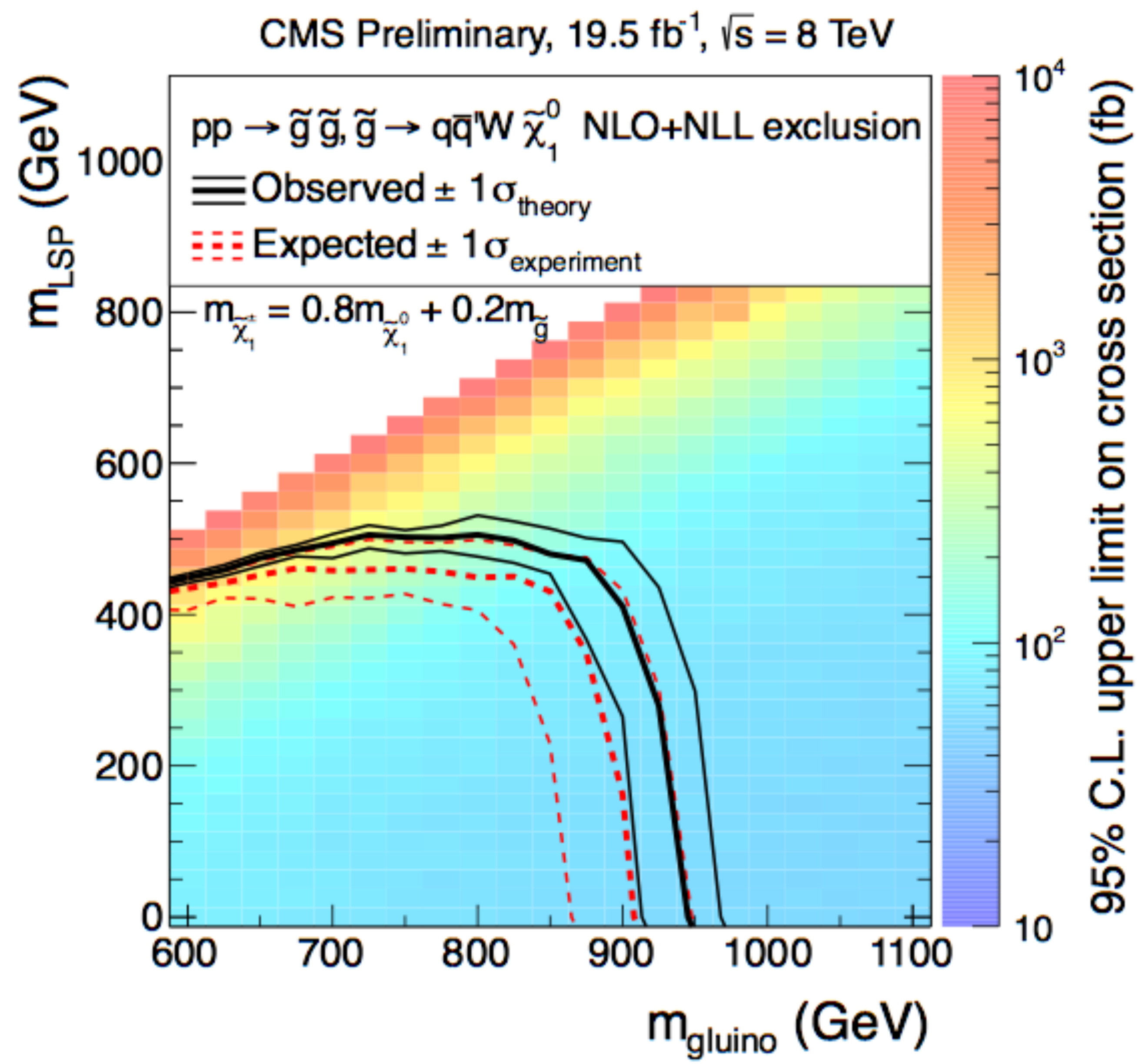
Gluino pair production. Gluino decays to sbottom, bottom. These production mode would be dominated is sbottom is the lightest squark.



Interpretation: model C1

gluino pair production, decaying to light quarks and a chargino via heavy squarks.





Interpretation EWKino