Interpretations of CMS SUSY searches in the context of RP Violation

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Outline

- **Introduction**
- Multijet searches
- Same-sign dilepton searches
- Multilepton searches
- Conclusion

Motivation

$$W_{\not R_p} = \mu_i H_u L_i + \frac{1}{2}\lambda_{ijk} L_i L_j E_k^c + \lambda'_{ijk} L_i Q_j D_k^c + \frac{1}{2}\lambda''_{ijk} U_i^c D_k^c D_k^c$$

Leptonic RPV | LQD RPV | Hadronic RPV

- RP violating (RPV) models have significantly different signatures than RP conserving (RPC) models
  - Resonances
  - Low MET
  - Unstable LSPs
  - Single particle production

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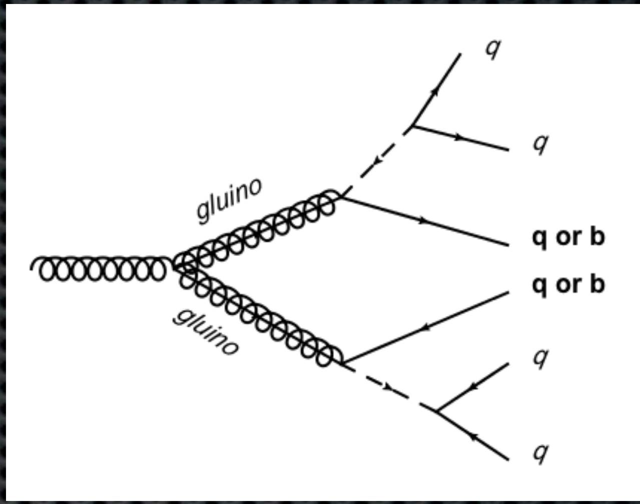
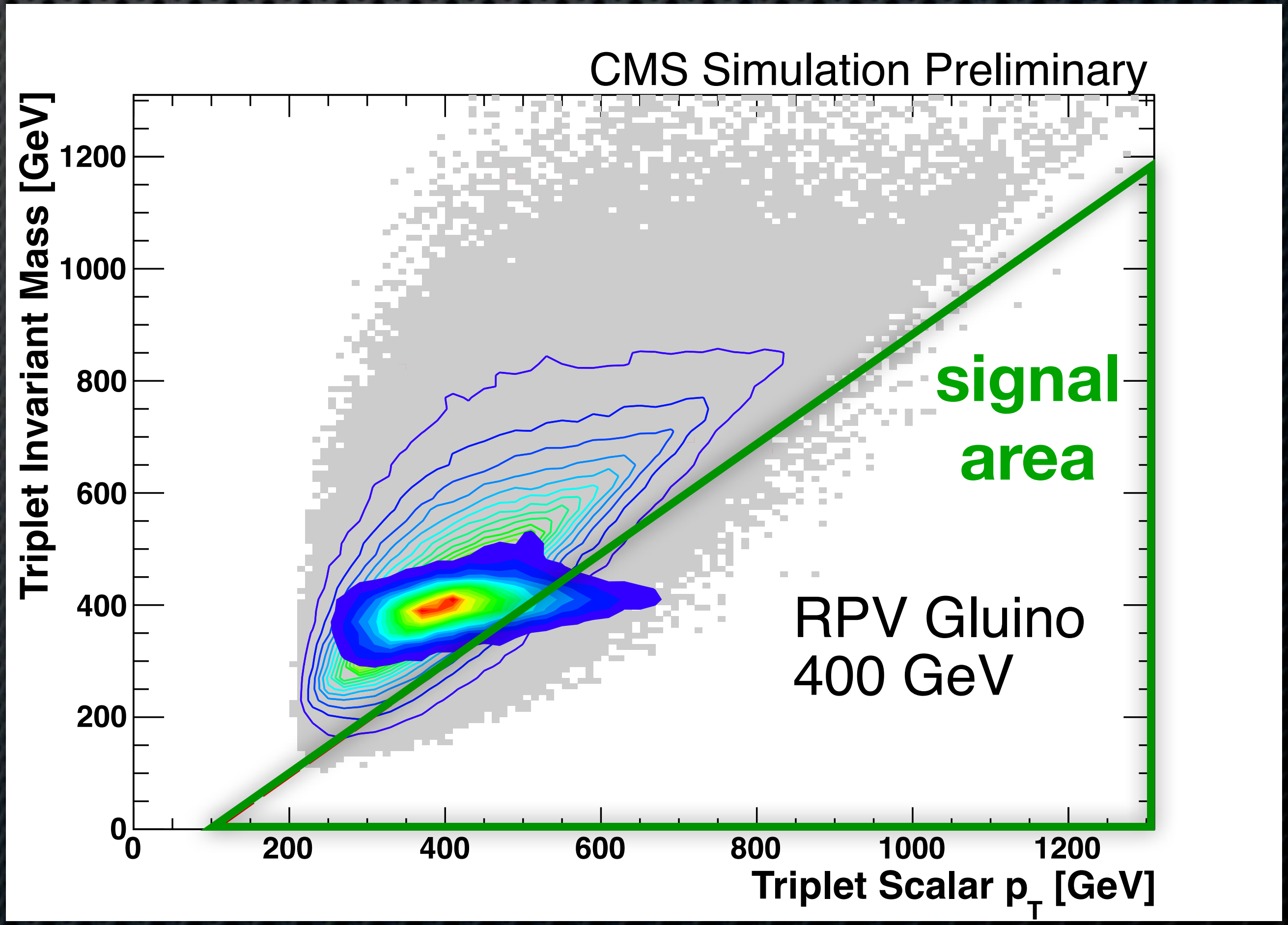
Multijet Analysis details



- Search for paired 3-jet resonances
- Therefore, look for events with 6 or more jets
  - Sixth jet $p_T > 110$ GeV
  - Form triplets and compare the mass with the scalar sum of the jet p_T
  - $M_{jjj} < \sum_j |p_{\mathrm{T},j}| - 110\ \mathrm{GeV}$
- Cut on sphericity: S > 0.4



EXO-12-049

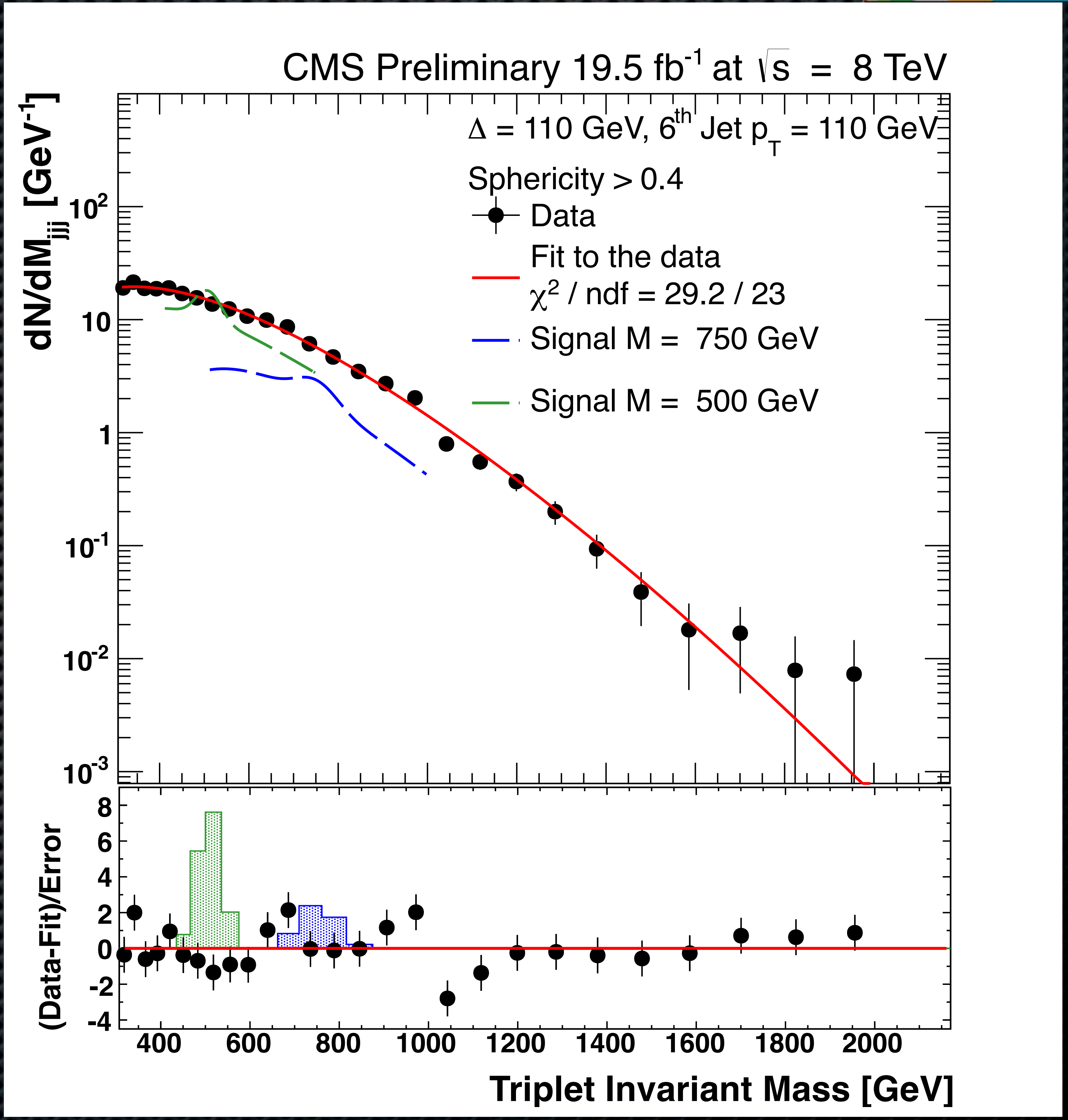
Additional details: http://cds.cern.ch/record/1563139

Multijet Analysis details

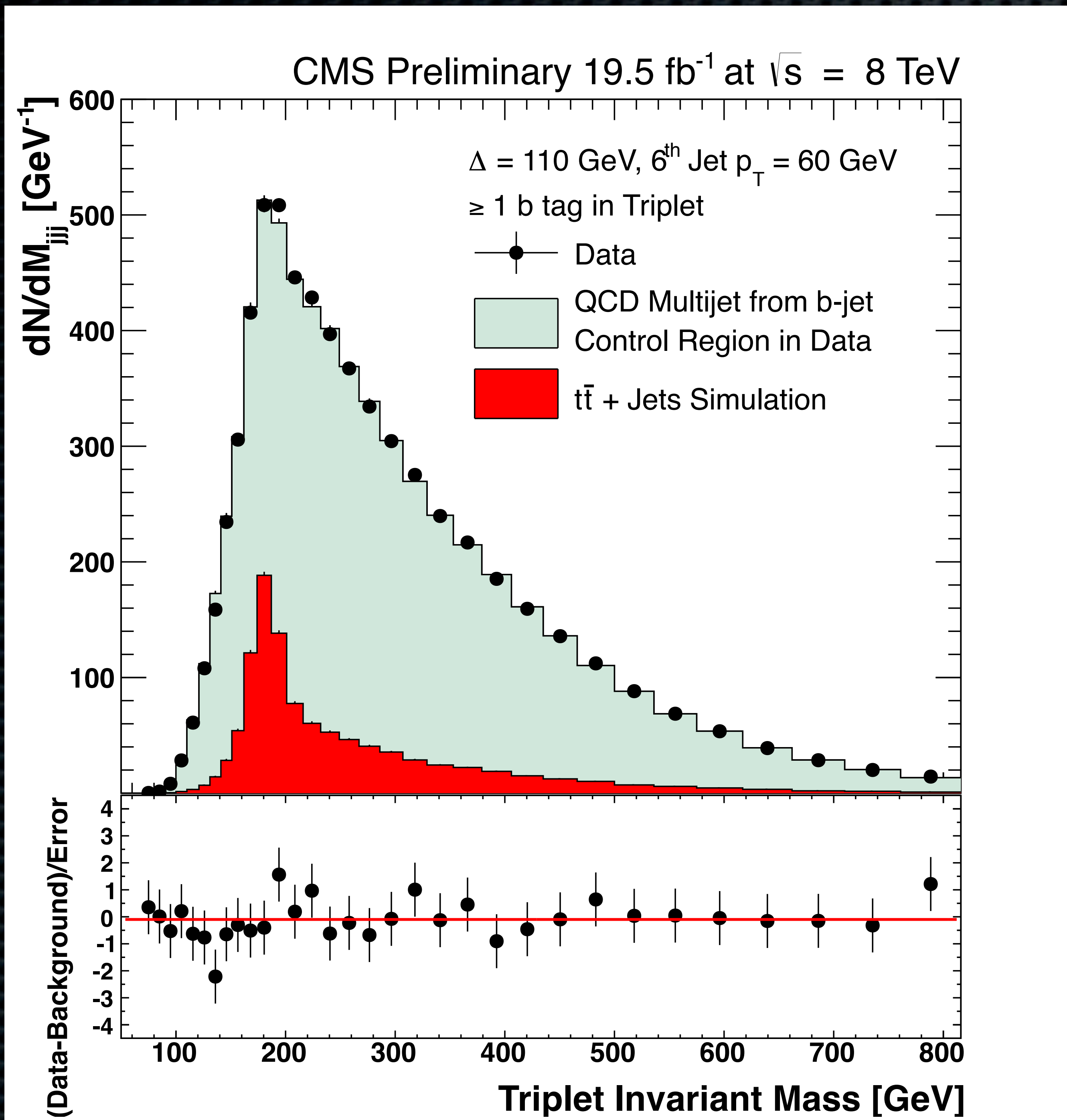
- Distinguish between events with and without b-tagged jets
- Fit the data to a four parameter function

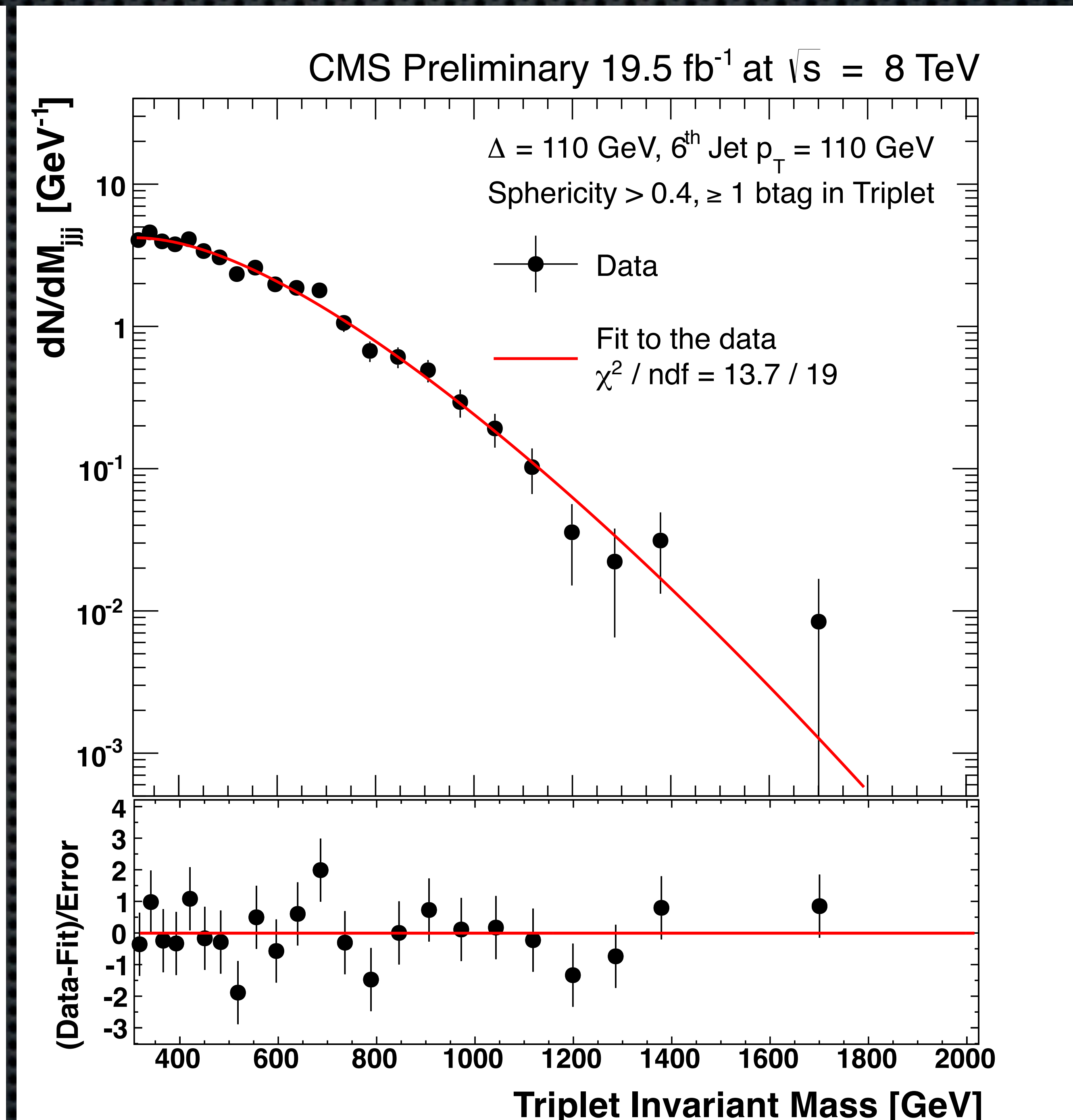
$$\frac{dN}{dx} = P_0 \frac{\left(1 - \frac{x}{\sqrt{s}}\right)^{P_1}}{\left(\frac{x}{\sqrt{s}}\right)^{P_2 + P_3 \log \frac{x}{\sqrt{s}}}}$$

EXO-12-049



Multijet Analysis details





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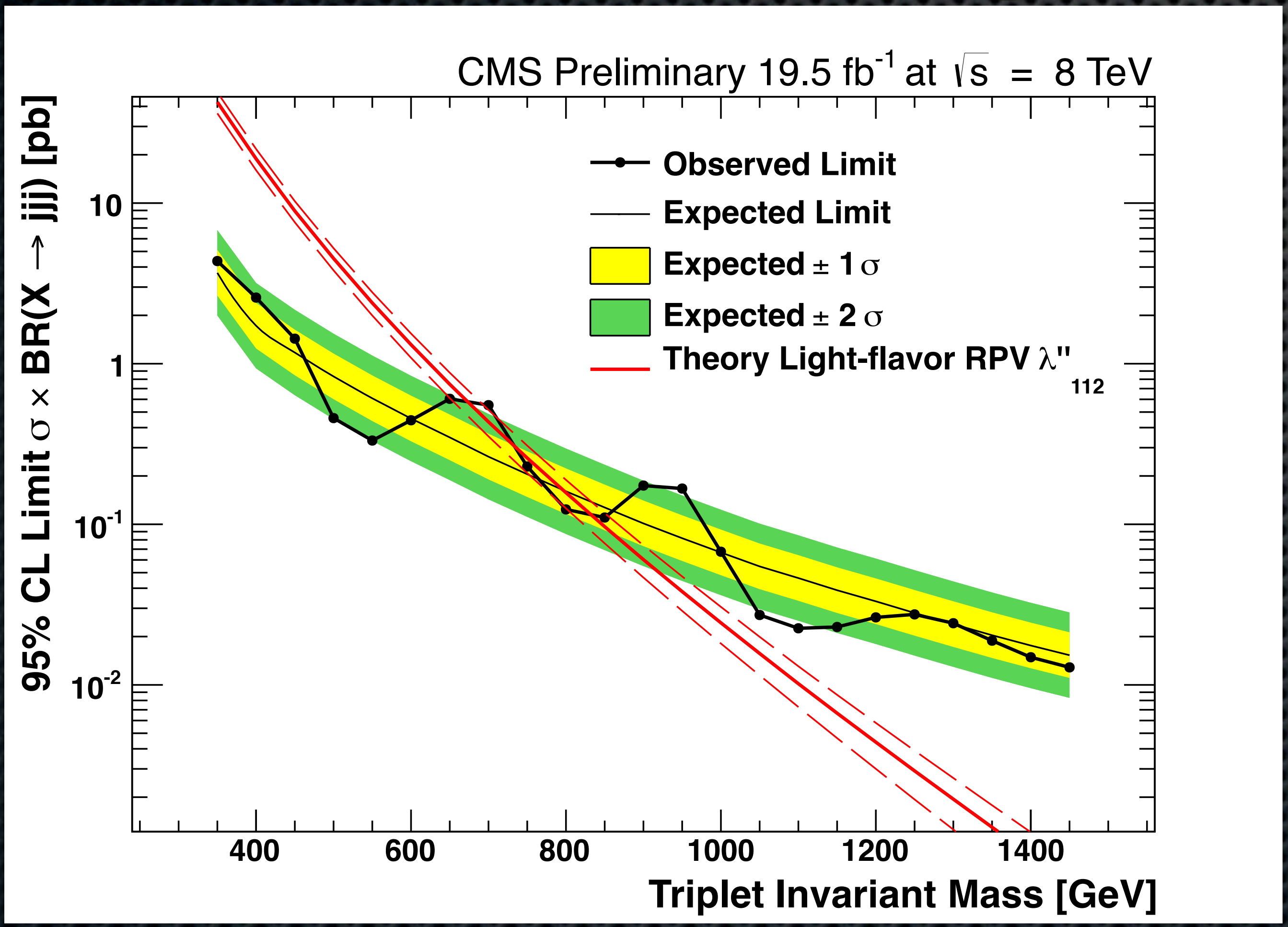
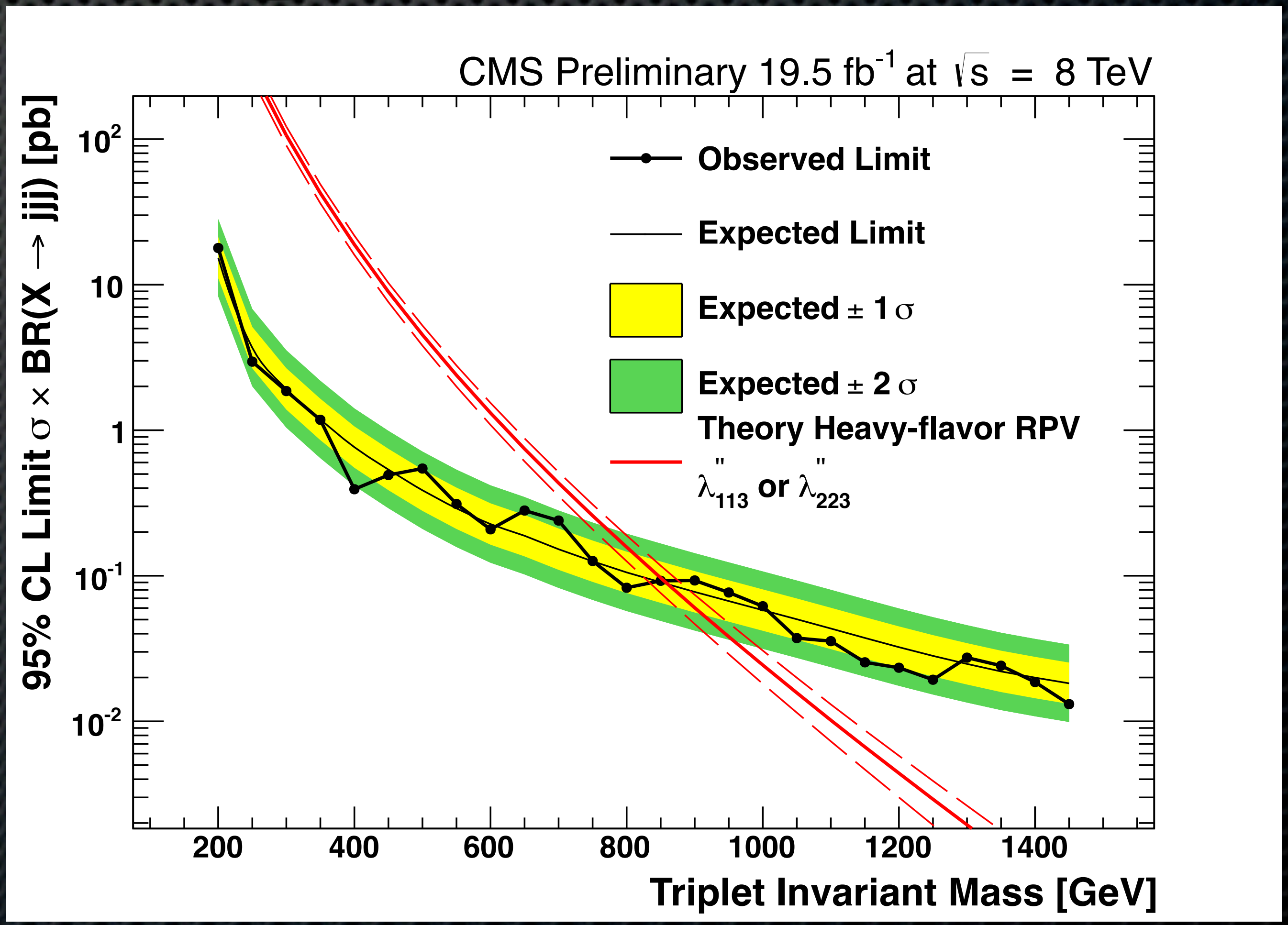
Multijet Interpretations

- Interpret the multijet resonance search in a model where the gluino decays via an UDD coupling to 3 jets
- Limits correspond to a light-flavor coupling $\lambda''_{112} \neq 0$ or a heavy-flavor coupling λ''_{113} or $\lambda''_{223} \neq 0$
- First limits for the heavy flavor coupling





EXO-12-049

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Same-sign analysis details

- Searching for new physics in events with isolated same-sign leptons and jets
- Looking in a variety of different search regions depending on the number of jets, the number of b-tagged jets, missing transverse energy, and hadronic transverse energy in each event

SUS-13-013

	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

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

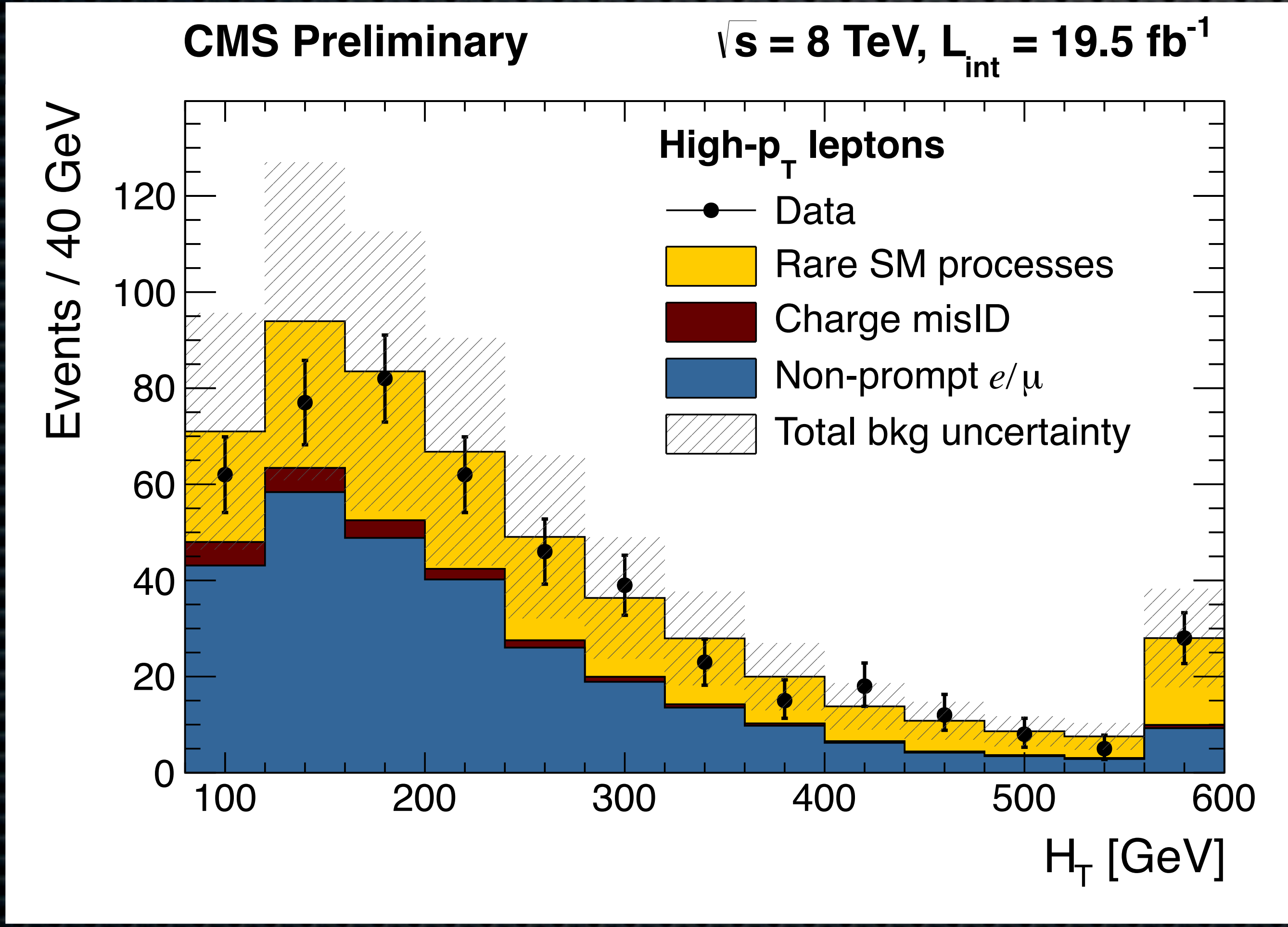
Additional details: http://cds.cern.ch/record/1563301

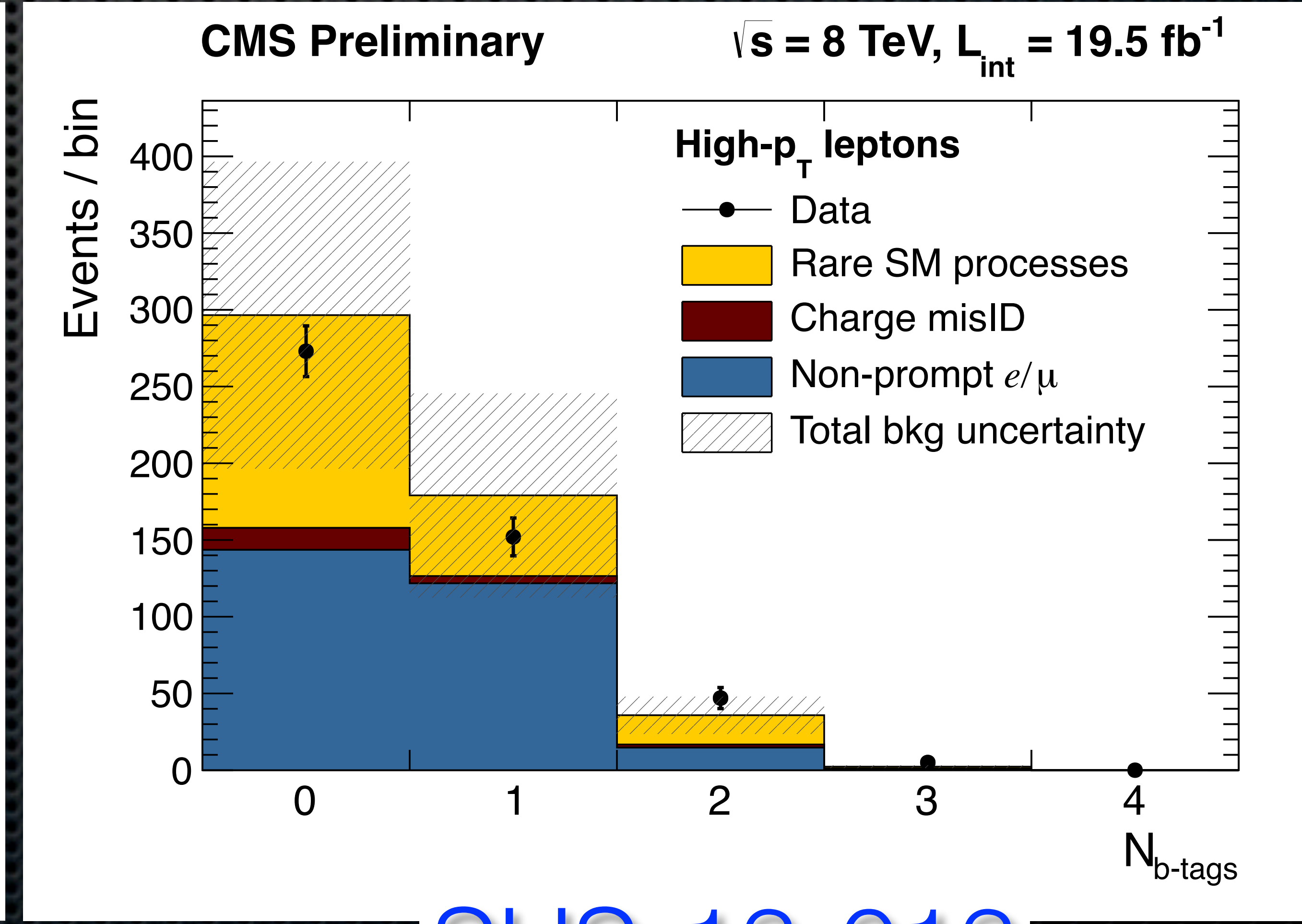
See talk by M. Buchmann (Mon)

Same-sign analysis details

- Good agreement between observations and expectations over a large number of distributions

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 Interpretations

- Similar model to the multijet analysis gluinos decaying to 3-jets via λ''_{323}
- Exclude gluinos with mass below 850 GeV

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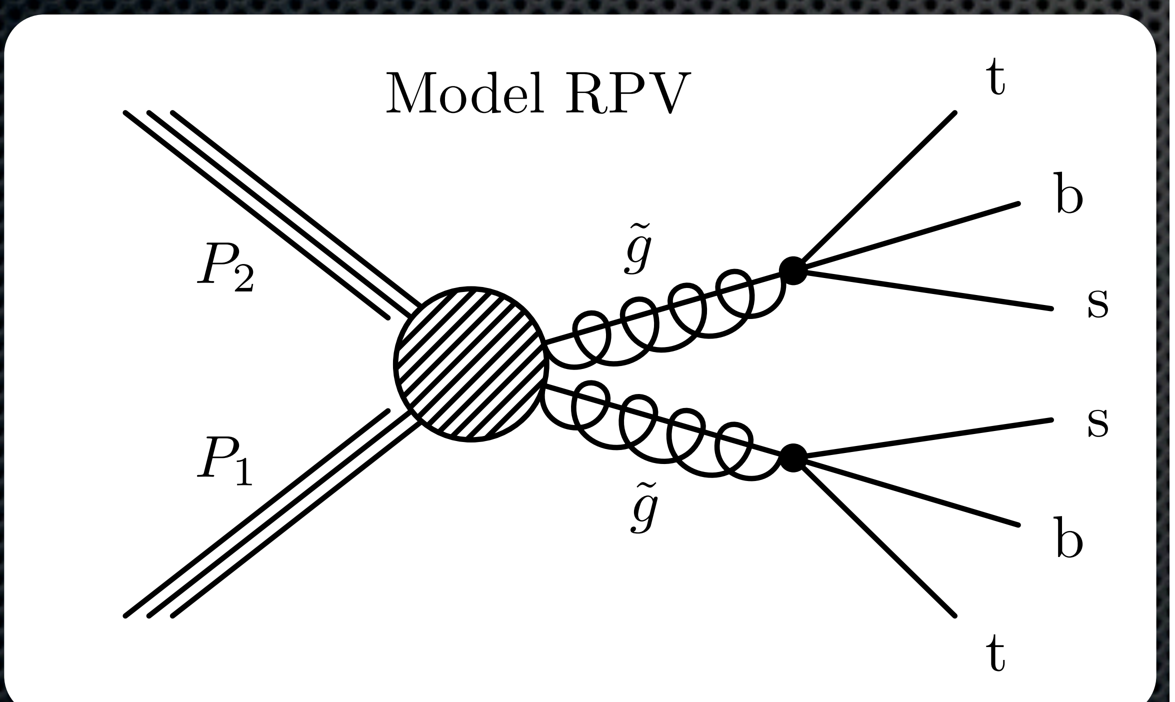

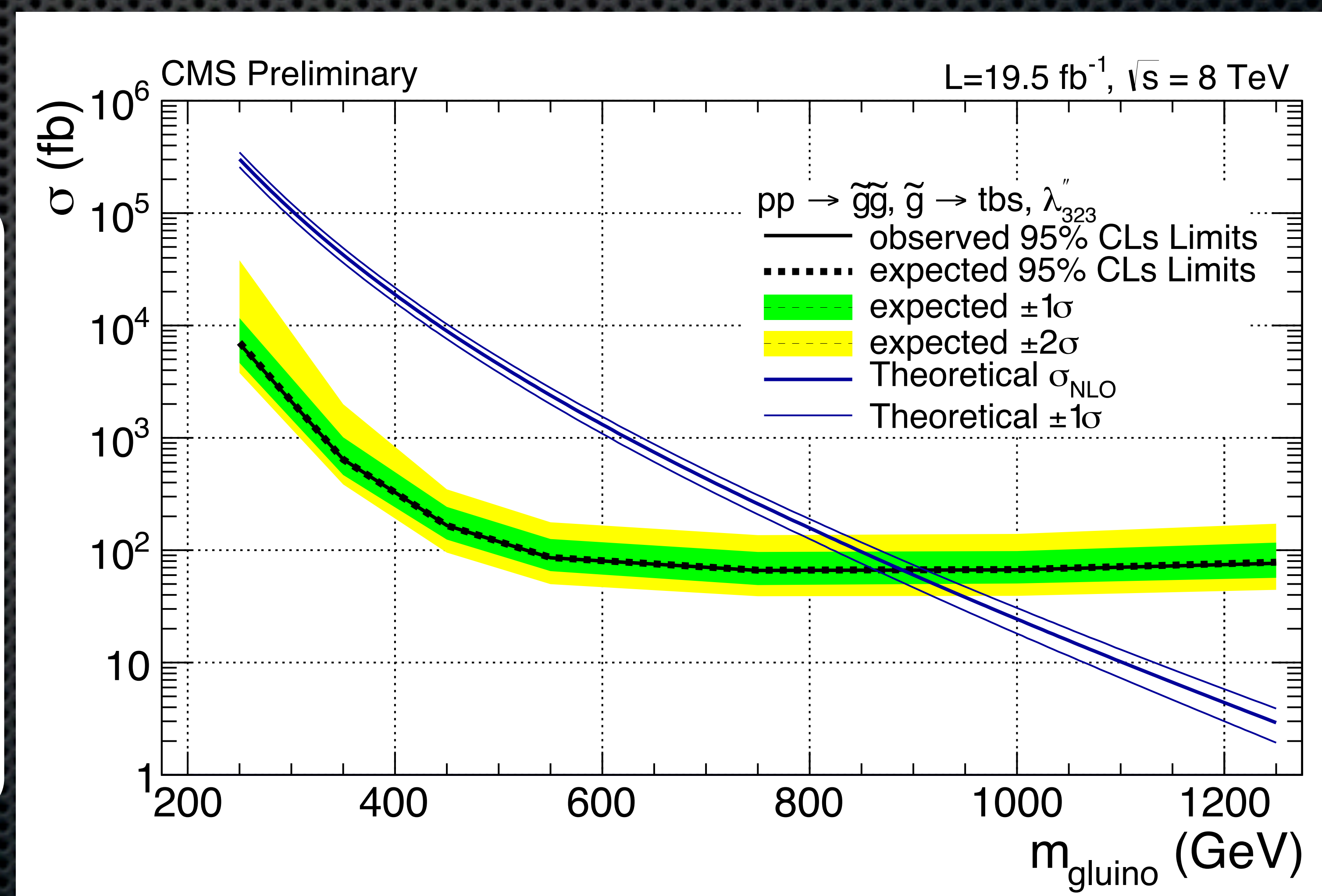

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- **Multilepton searches**
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Multilepton Analysis Details

- Search for new physics in events with 3 or more leptons
- Bin in number of leptons (electrons + muons + taus)
  - Separate in number of taus
- Separate events depending on how many OSSF pairs there are and whether they have a mass consistent with a Z
- Separate events depending on whether or not they contain b-tagged jets or not
- Bin in ST, the sum of MET, H_T, and lepton p_T's

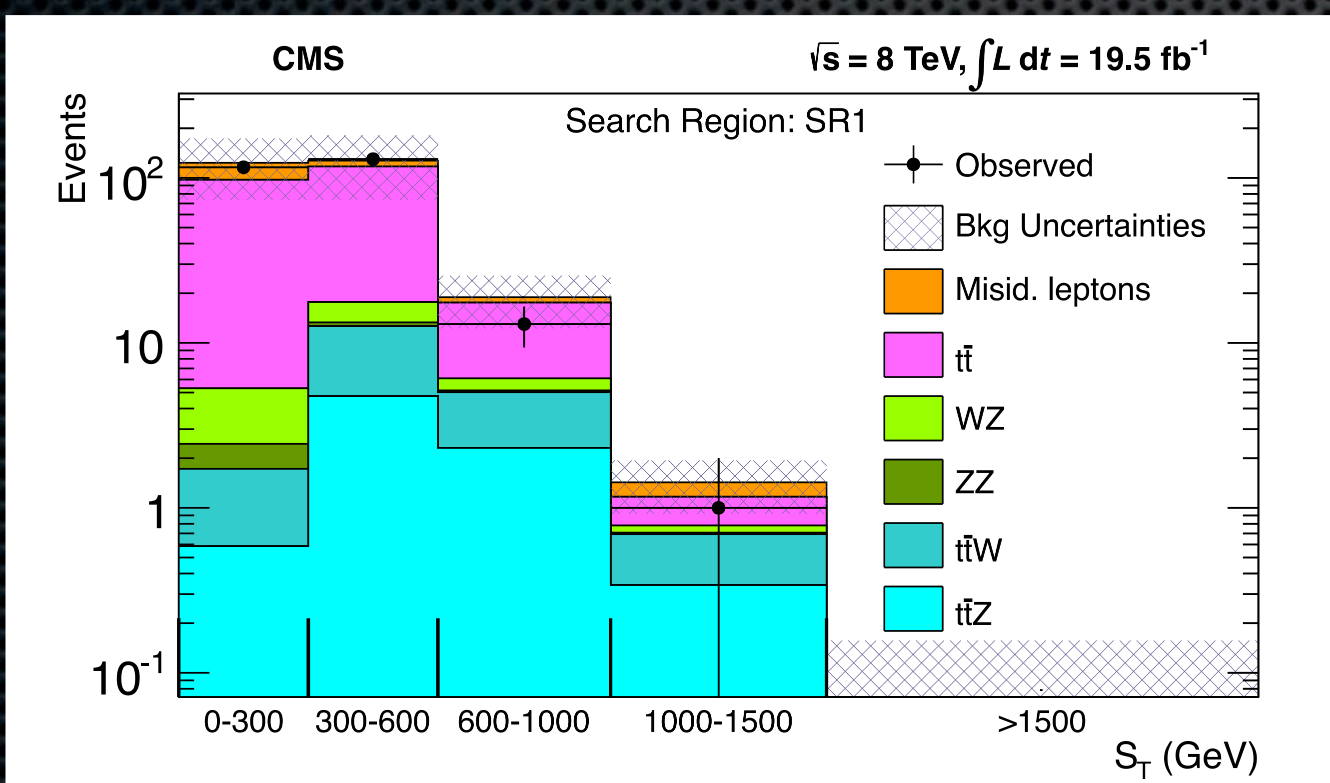
SUS-13-003

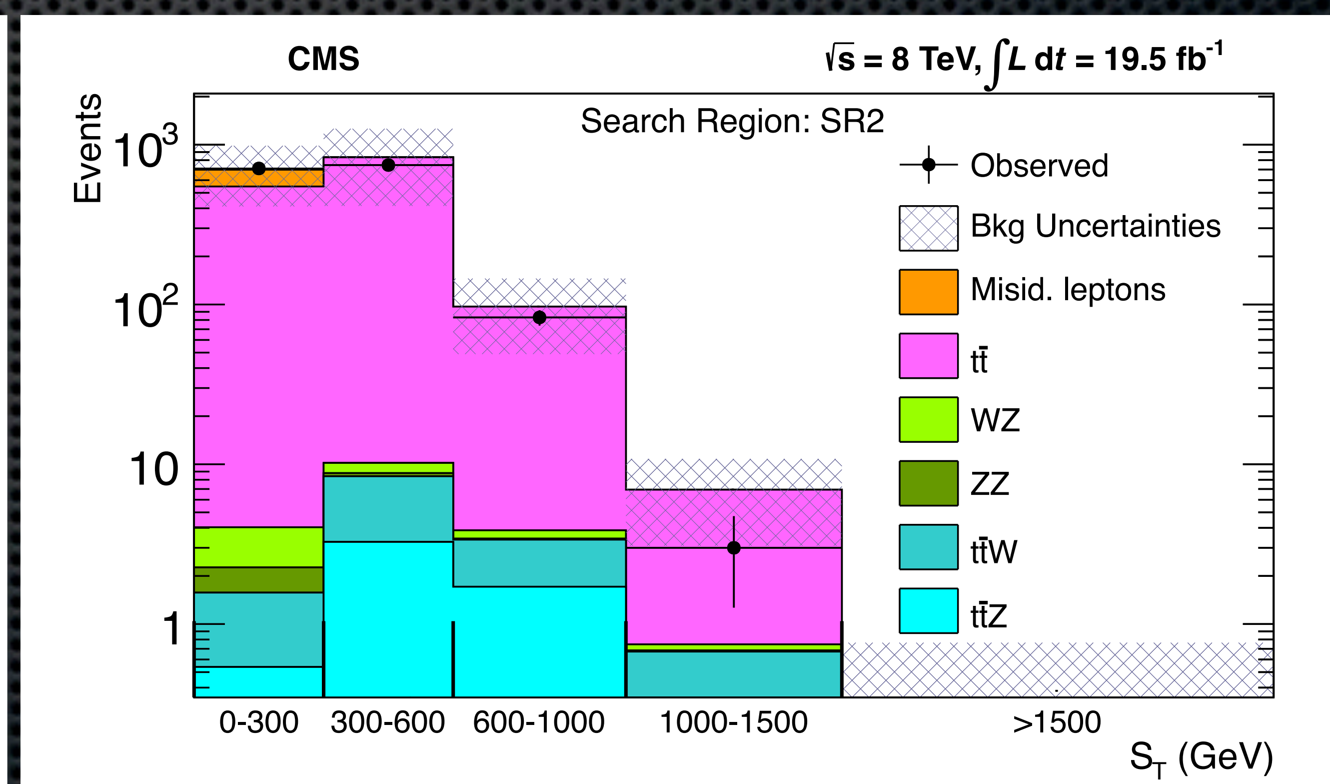
Additional details: http://cds.cern.ch/record/1558437
and https://cds.cern.ch/record/1550552

Results - Three Leptons

Require a b-jet and all OSSF pairs off-Z

SR	N_L	N_τ	$0 < S_T < 300$ obs	$0 < S_T < 300$ exp	$300 < S_T < 600$ obs	$300 < S_T < 600$ exp	$600 < S_T < 1000$ obs	$600 < S_T < 1000$ exp	$1000 < S_T < 1500$ obs	$1000 < S_T < 1500$ exp	$S_T > 1500$ obs	$S_T > 1500$ exp
SR1	3	0	116	123 ± 50	130	127 ± 54	13	18.9 ± 6.7	1	1.43 ± 0.51	0	0.208 ± 0.096
SR2	3	≥ 1	710	698 ± 287	746	837 ± 423	83	97 ± 48	3	6.9 ± 3.9	0	0.73 ± 0.49
SR3	4	0	0	0.186 ± 0.074	1	0.43 ± 0.22	0	0.19 ± 0.12	0	0.037 ± 0.039	0	0.000 ± 0.021
SR4	4	≥ 1	1	0.89 ± 0.42	0	1.31 ± 0.48	0	0.39 ± 0.19	0	0.019 ± 0.026	0	0.000 ± 0.021
SR5	3	0	-	-	-	-	165	174 ± 53	16	21.4 ± 8.4	5	2.18 ± 0.99
SR6	3	≥ 1	-	-	-	-	276	249 ± 80	17	19.9 ± 6.8	0	1.84 ± 0.83
SR7	4	0	-	-	-	-	5	8.2 ± 2.6	2	0.96 ± 0.37	0	0.113 ± 0.056
SR8	4	≥ 1	-	-	-	-	2	3.8 ± 1.3	0	0.34 ± 0.16	0	0.040 ± 0.033



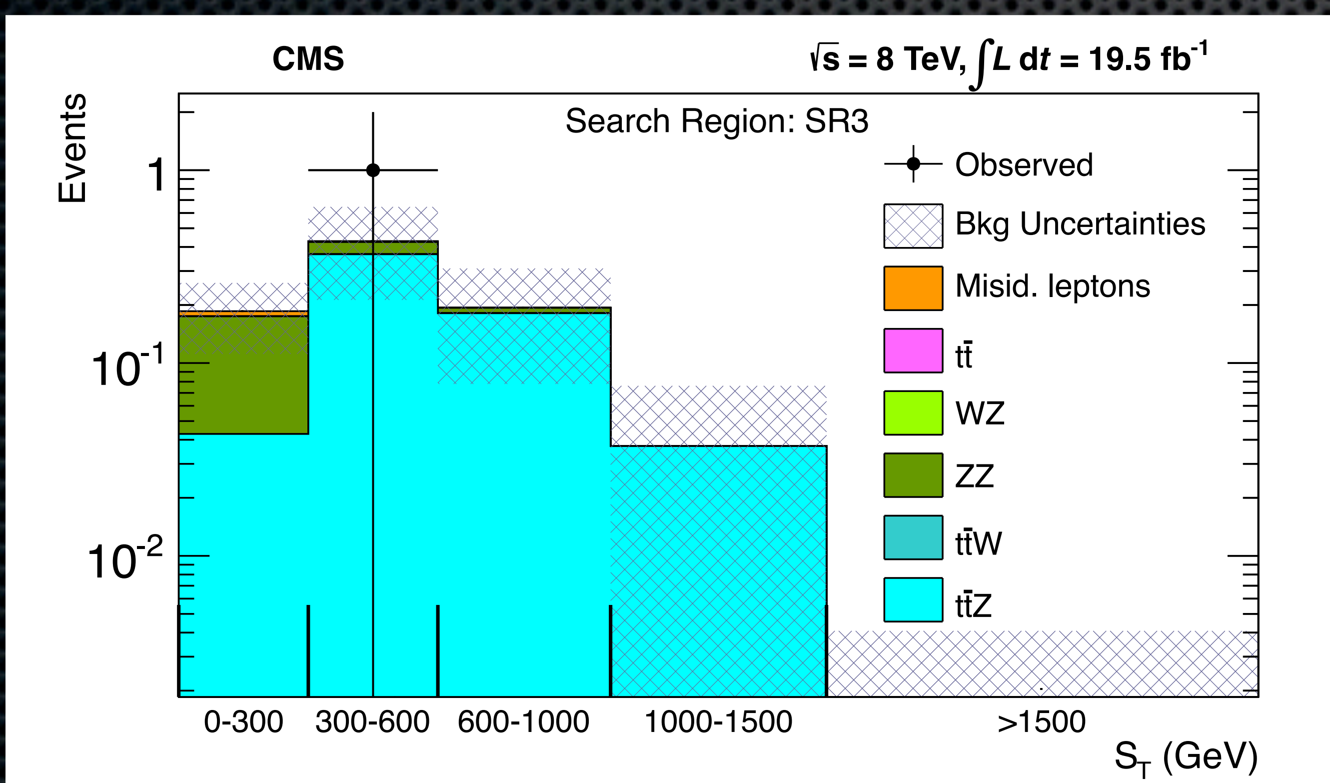


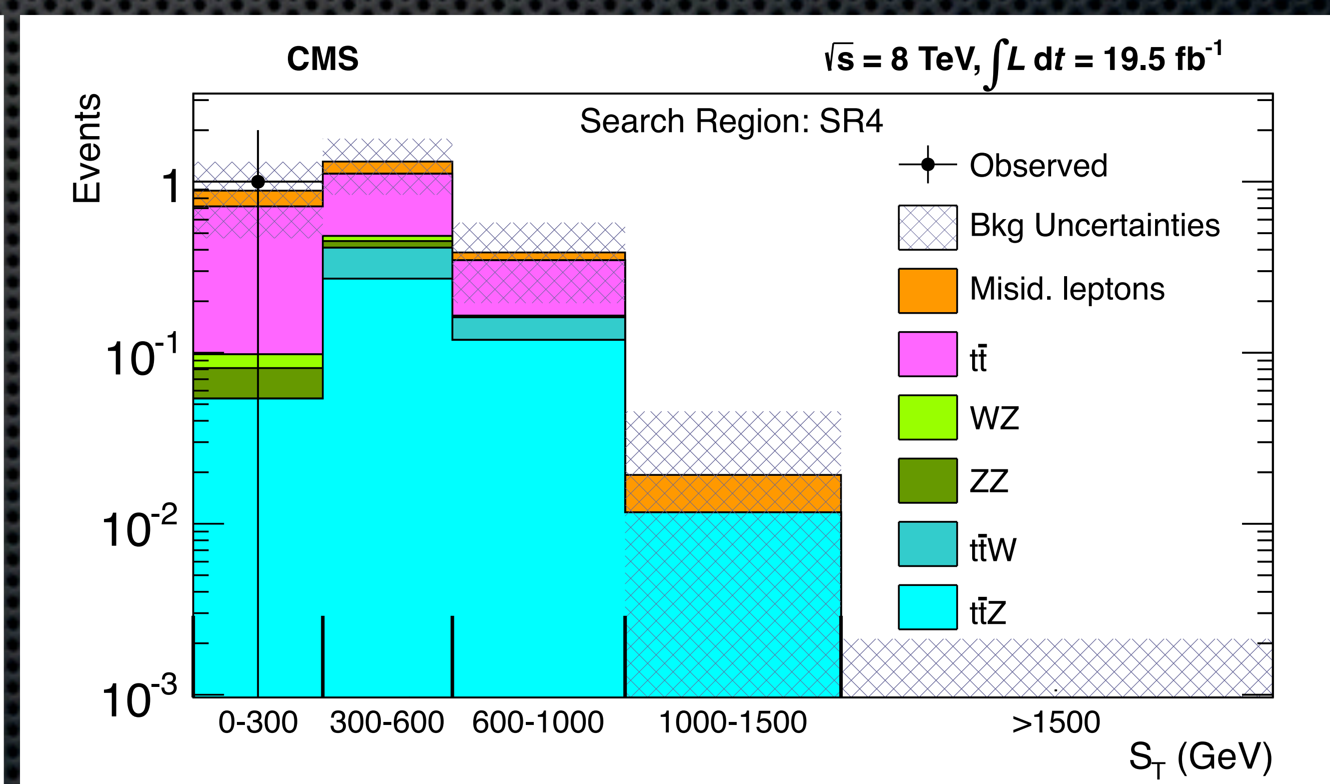
SUS-13-003

Results - Four Leptons

Require a b-jet and all OSSF pairs off-Z

SR	N_L	N_τ	$0 < S_T < 300$		$300 < S_T < 600$		$600 < S_T < 1000$		$1000 < S_T < 1500$		$S_T > 1500$	
			obs	exp	obs	exp	obs	exp	obs	exp	obs	exp
SR1	3	0	116	123 ± 50	130	127 ± 54	13	18.9 ± 6.7	1	1.43 ± 0.51	0	0.208 ± 0.096
SR2	3	≥ 1	710	698 ± 287	746	837 ± 423	83	97 ± 48	3	6.9 ± 3.9	0	0.73 ± 0.49
SR3	4	0	0	0.186 ± 0.074	1	0.43 ± 0.22	0	0.19 ± 0.12	0	0.037 ± 0.039	0	0.000 ± 0.021
SR4	4	≥ 1	1	0.89 ± 0.42	0	1.31 ± 0.48	0	0.39 ± 0.19	0	0.019 ± 0.026	0	0.000 ± 0.021
SR5	3	0	-	-	-	-	165	174 ± 53	16	21.4 ± 8.4	5	2.18 ± 0.99
SR6	3	≥ 1	-	-	-	-	276	249 ± 80	17	19.9 ± 6.8	0	1.84 ± 0.83
SR7	4	0	-	-	-	-	5	8.2 ± 2.6	2	0.96 ± 0.37	0	0.113 ± 0.056
SR8	4	≥ 1	-	-	-	-	2	3.8 ± 1.3	0	0.34 ± 0.16	0	0.040 ± 0.033





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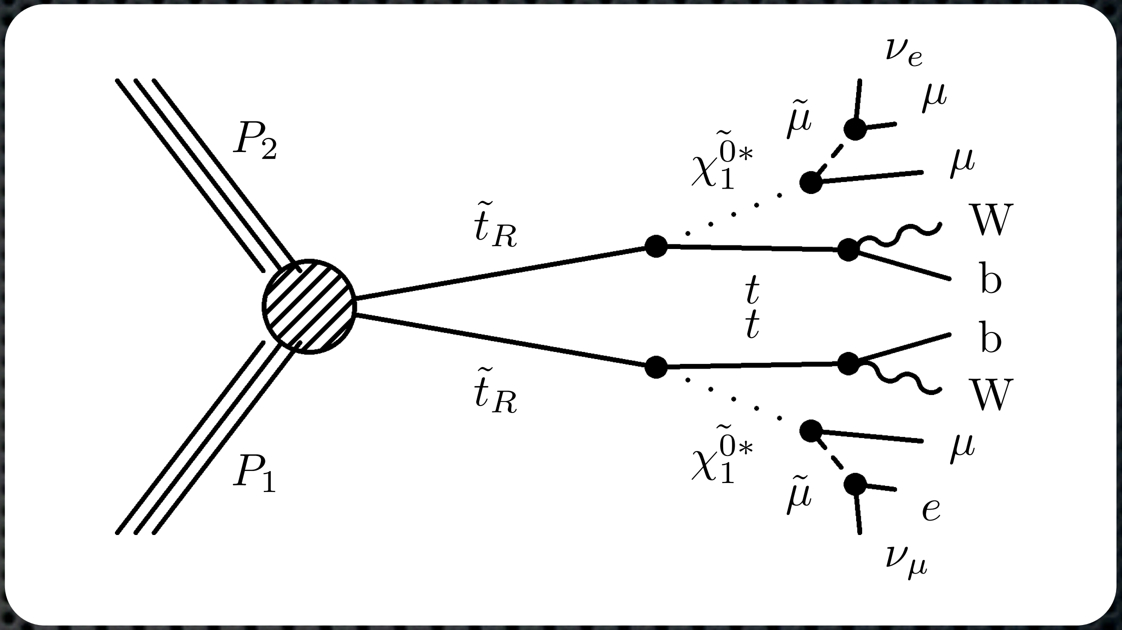
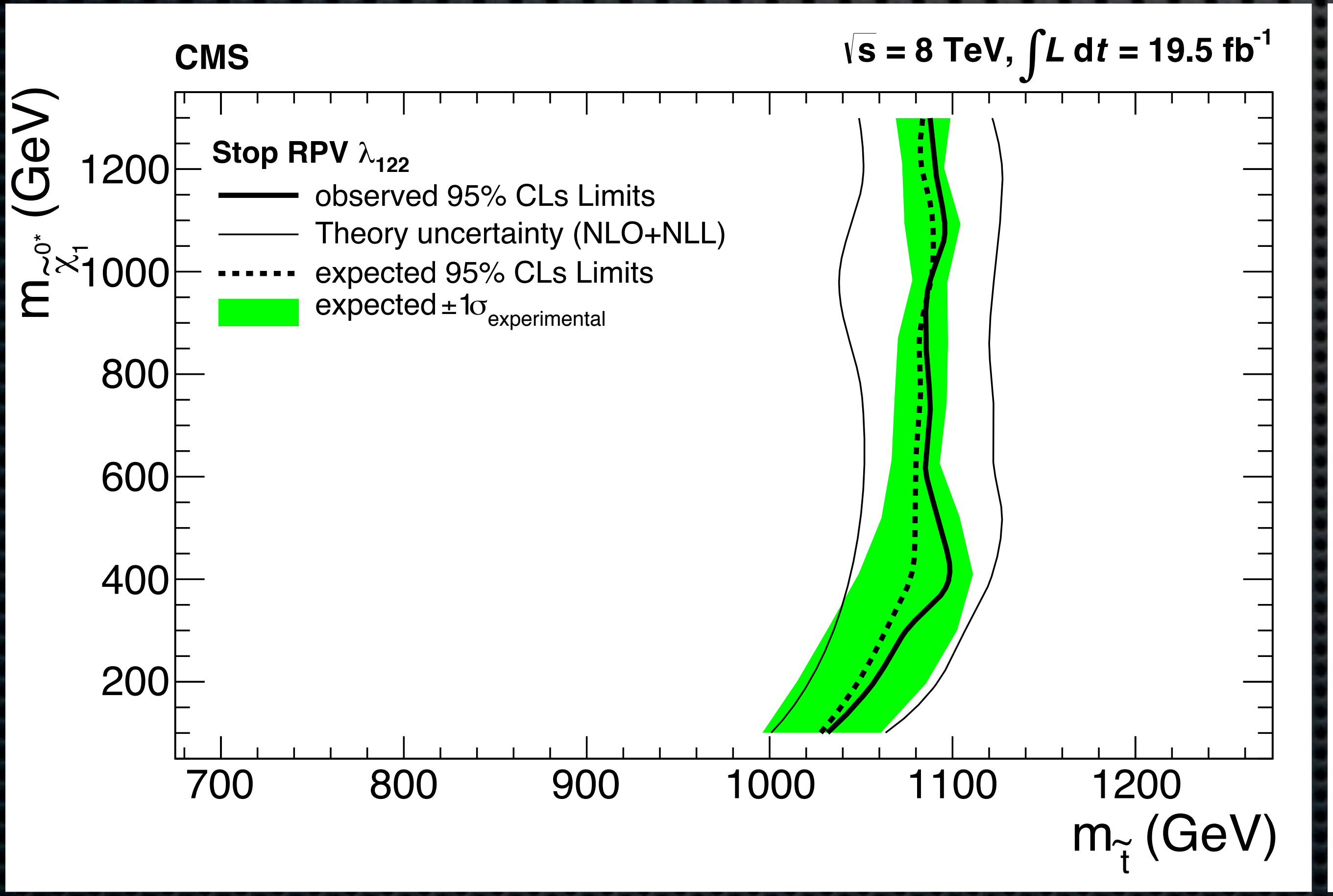
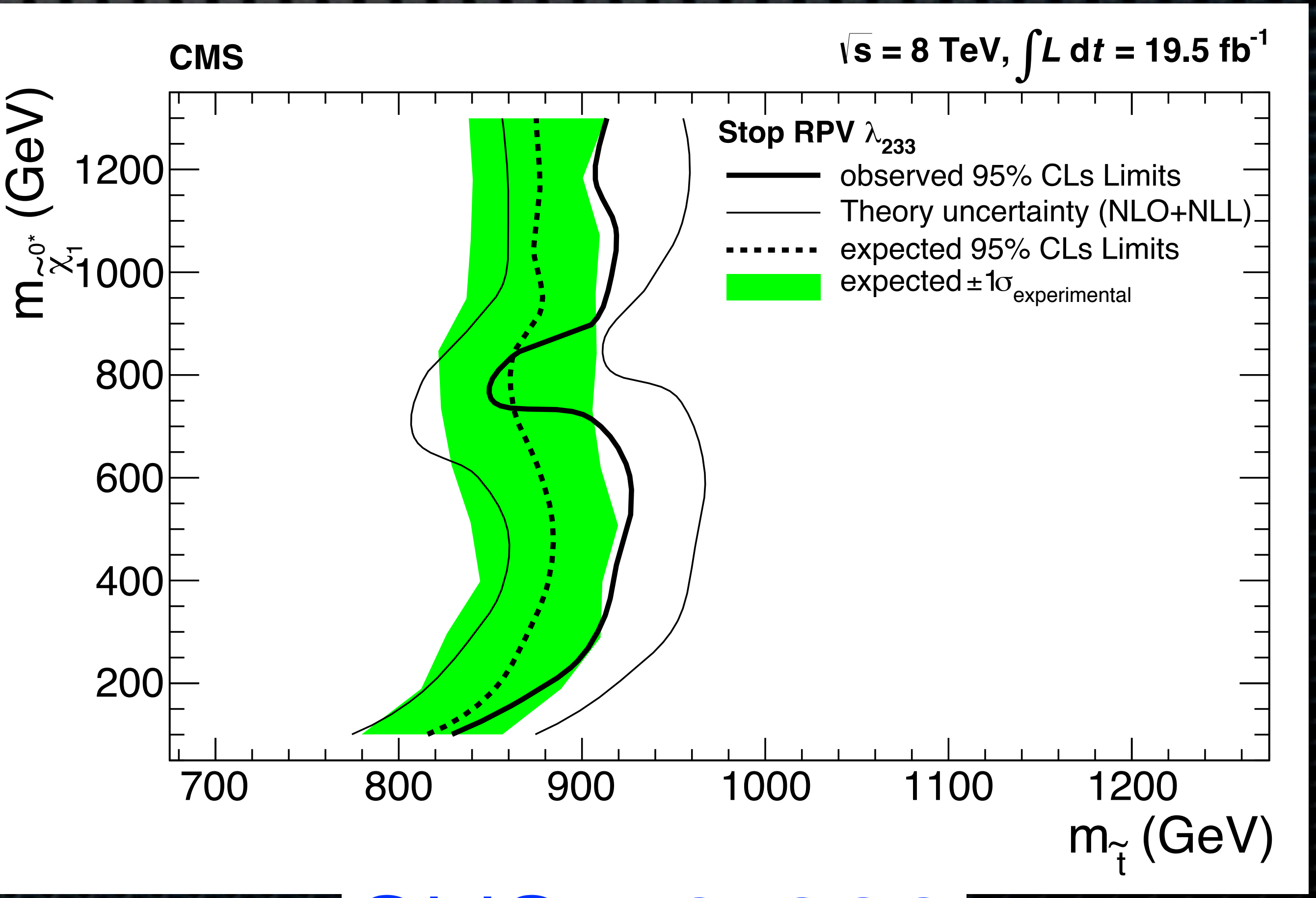
Multilepton Interpretations

- Interpret the results in a model with stop-pair production and LLE couplings







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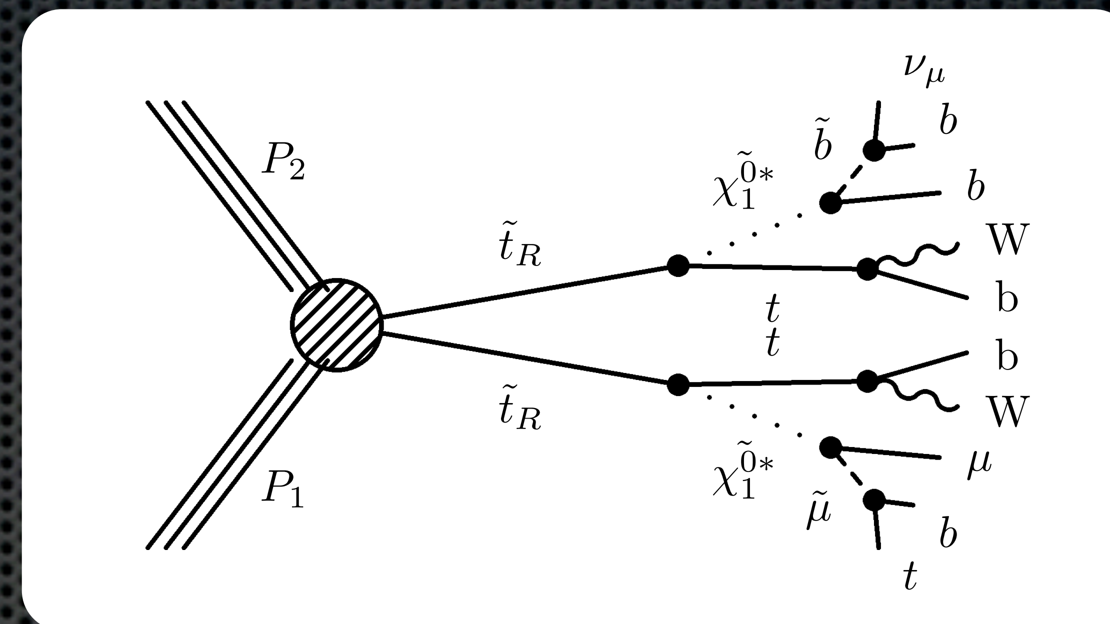
Multilepton Interpretations

- Interpret the results in the same model with $\lambda'_{233} \neq 0$



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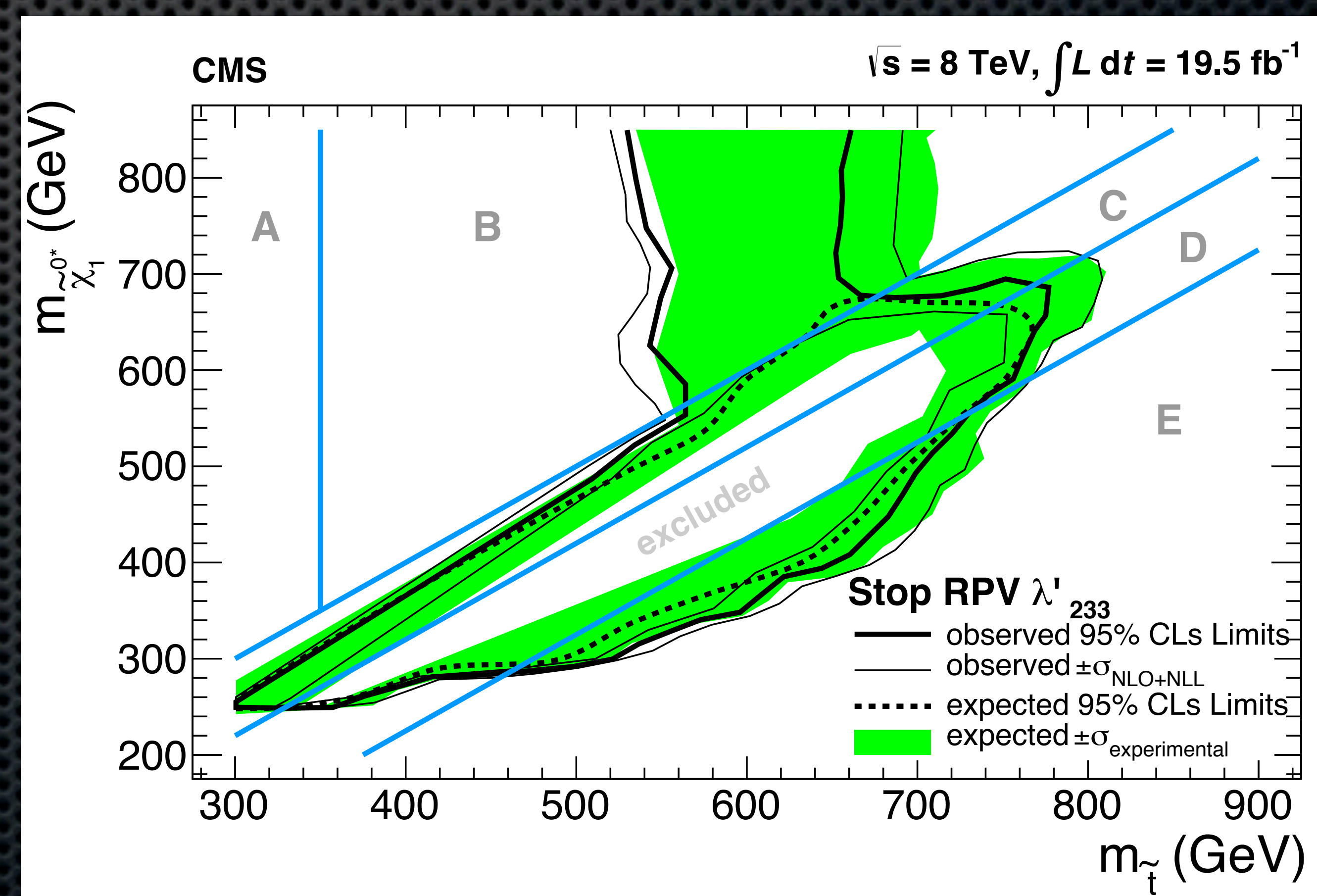
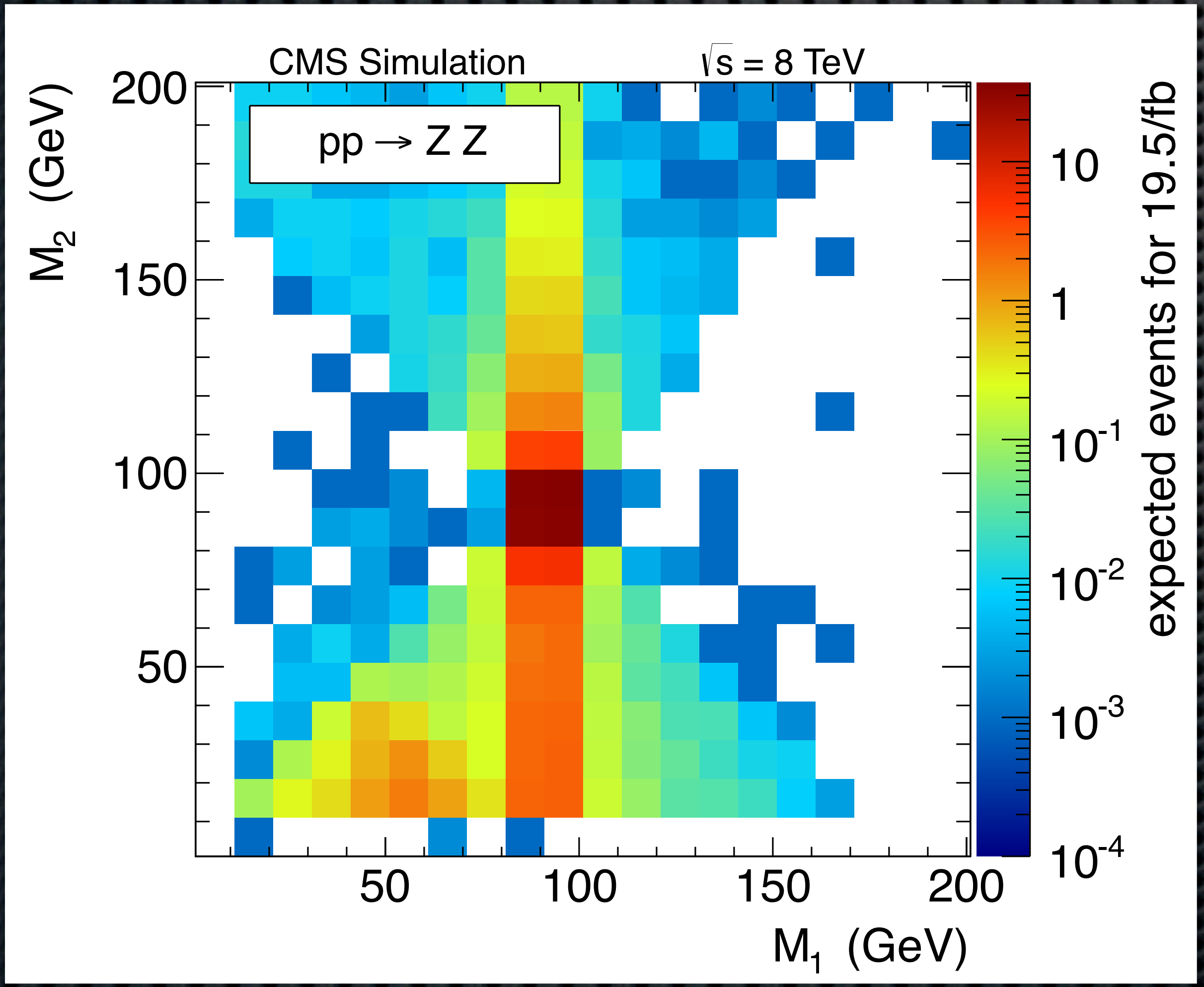
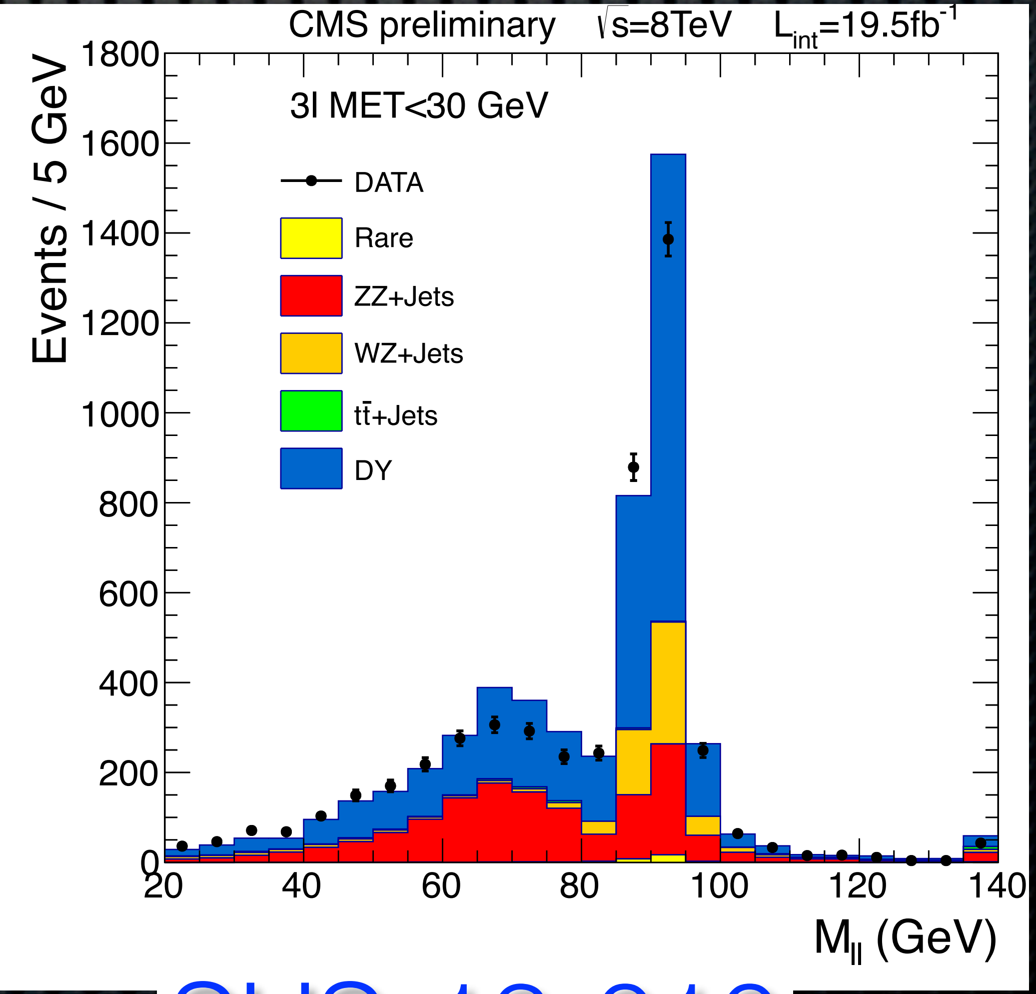
region label	kinematic region	stop decay mode(s)
A	$m_t < m_{\tilde{t}} < 2m_t, m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\nu b\bar{b}$
B	$2m_t < m_{\tilde{t}} < m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\mu t\bar{b} + t\nu b\bar{b}$
C	$m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_W + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to \ell\nu b\tilde{\chi}_1^0 + jjb\tilde{\chi}_1^0$
D	$m_W + m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_t + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to Wb\tilde{\chi}_1^0$
E	$m_t + m_{\tilde{\chi}_1^0} < m_{\tilde{t}}$	$\tilde{t} \to t\tilde{\chi}_1^0$



Multilepton M_1 vs M_2 details

- We have additional interpretations that focus events with four electrons or muons, removing other kinematic requirements
- Use the 2-dimensional mass distribution in dilepton mass of the two OSSF pairs





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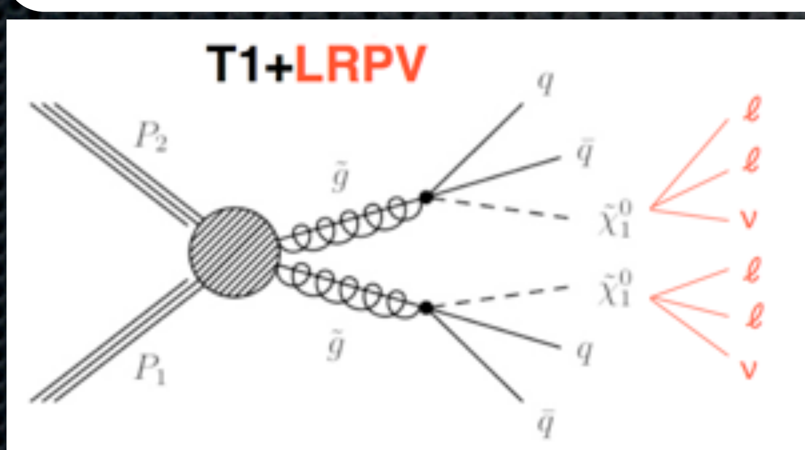
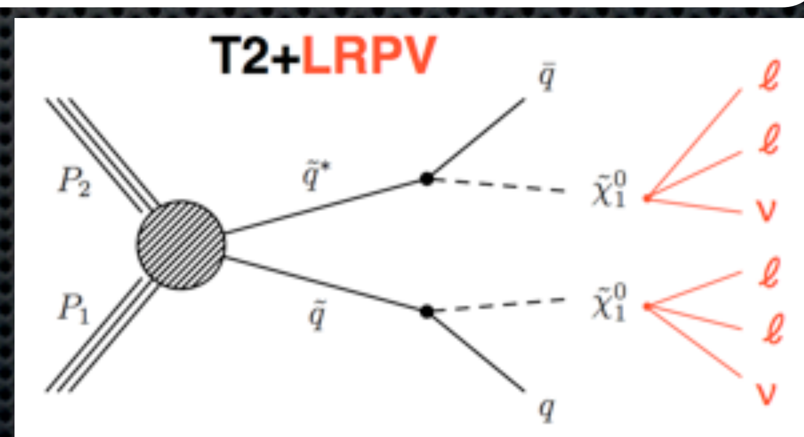
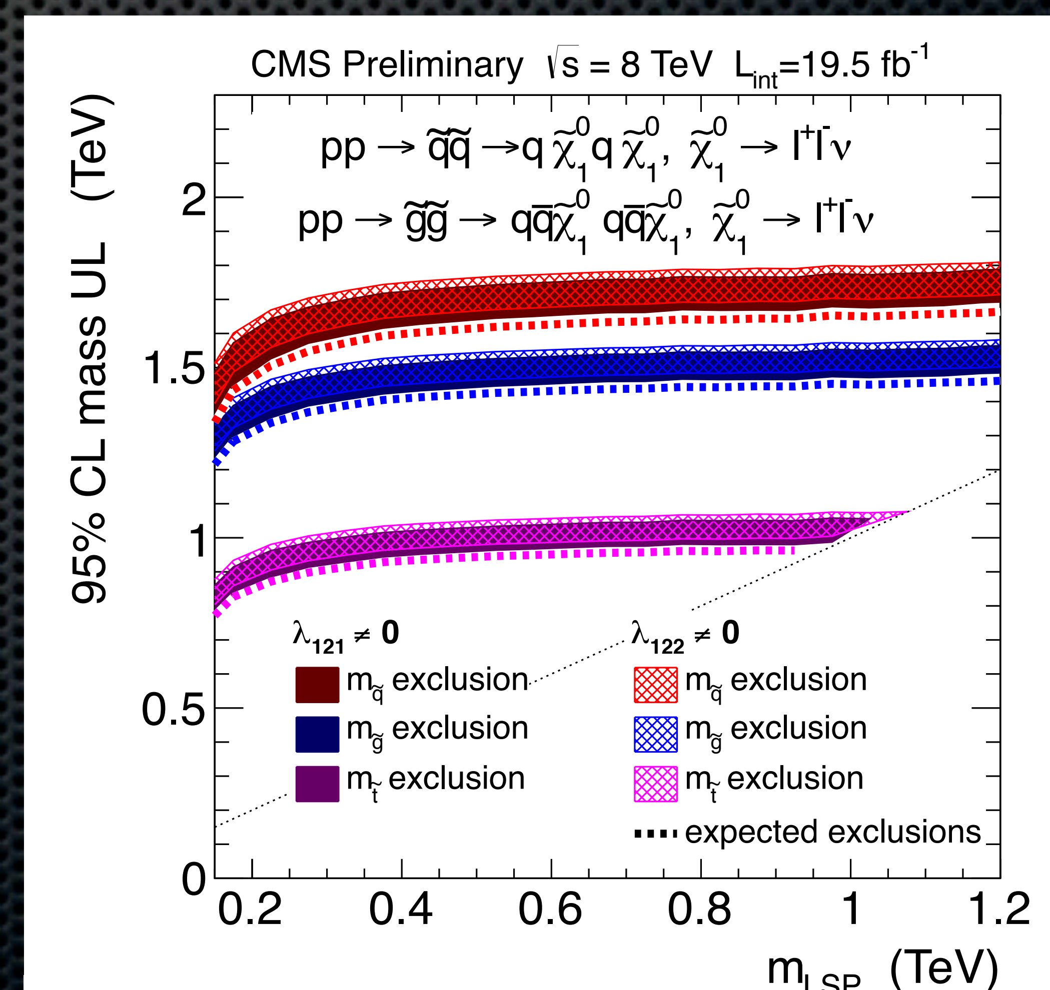
Multilepton Interpretations

- We interpret these results in separate models with gluino or squark pair production and using LLE couplings λ_{121} and $\lambda_{122} \neq 0$

		$M_1 < 76$ GeV	$76 < M_1 < 106$ GeV	$M_1 > 106$ GeV
$M_2 > 106$ GeV	all backgrounds	1.4±0.5	18±4	0.47±0.10
	observed	0	20	0
$76 < M_2 < 106$ GeV	all backgrounds	0.52±0.30	153*	0.16±0.06
	observed	0	160	0
$M_2 < 76$ GeV	all backgrounds	10.4±2.0	35±8	1.0±0.2
	observed	14	30	1







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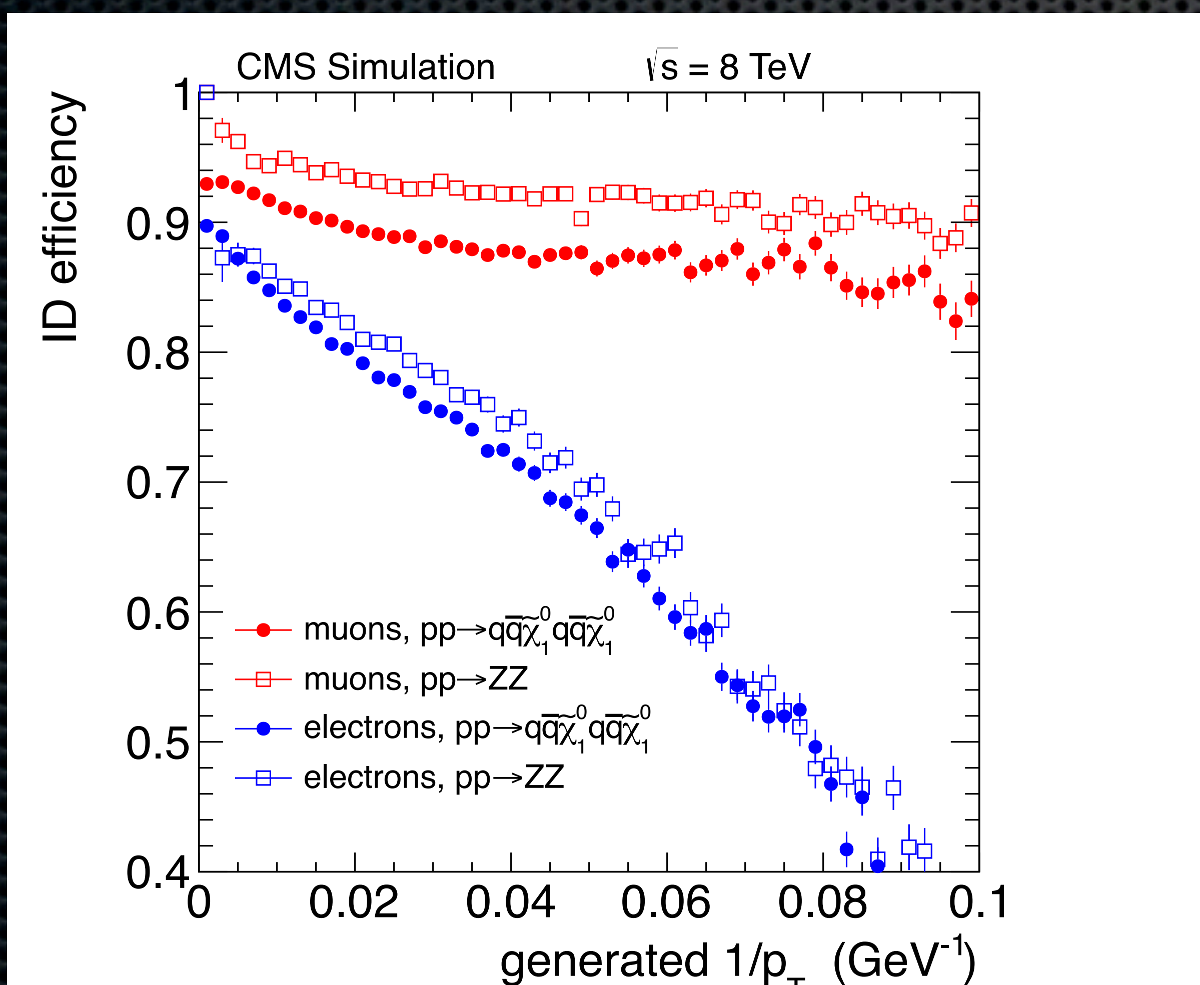
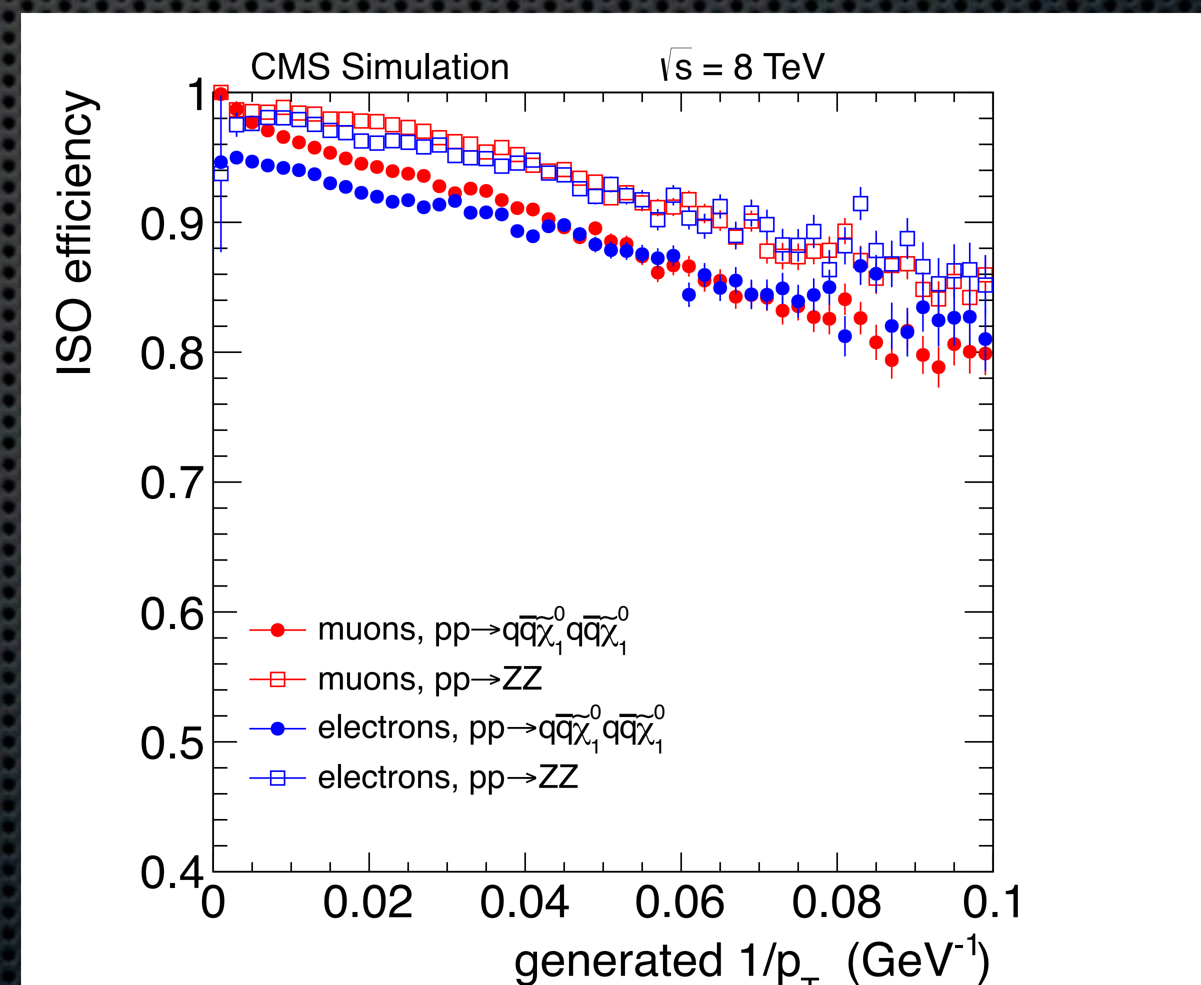
Multilepton efficiency model

- We produce the electron and muon ID and isolation efficiencies as a function of $1/p_T$ (generator) for one of the signal samples and the ZZ background MC sample





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Conclusions

- CMS searches exclude parameter space in a broad set of different models including all three trilinear RPV Yukawa couplings
- We show first limit of hadronic RPV couplings that include heavy flavor in the all-hadronic resonance search
- Limits in the stop model with LLE couplings achieve 1 TeV exclusions on the stop mass
- These searches close the kinematic gap in the low MET region that most RPC searches overlook

TeV exclusion of Stop

- Looking in the ~20 most sensitive channels for the grid point mstop = 1050, mneutralino = 500

observed	background	expected signal
0	0.14 +/- 0.08	3.47 +/- 0.24

- This point has a cross section of 0.28 fb (with 30% uncertainty), corresponding to a total of 5.46 expected events

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