LHCP 2013 - First Large Hadron Collider Physics Conference

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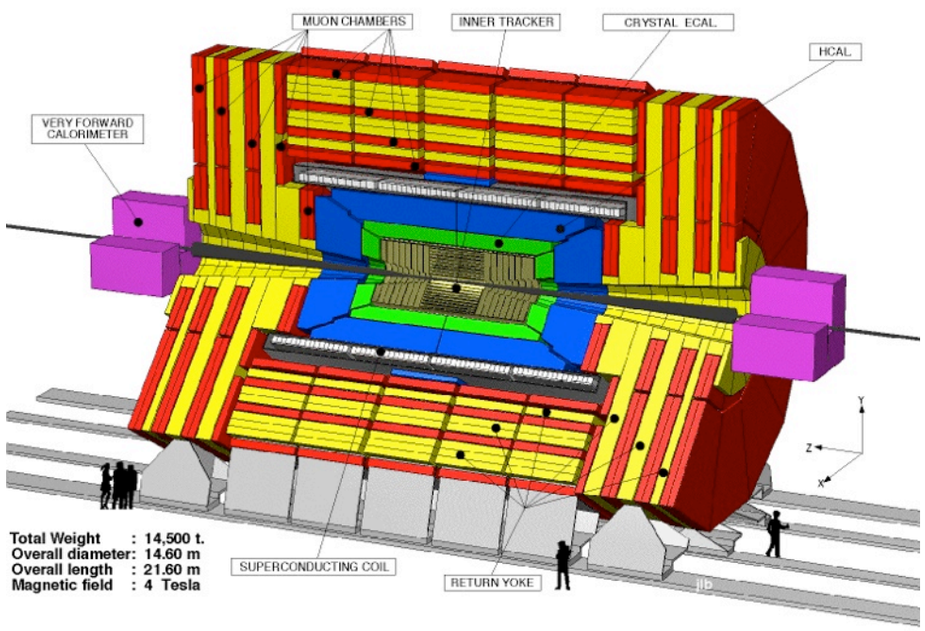
Hotel Catalonia Barcelona Plaza, Barcelona - Spain
Europe/Zurich timezone



Search for RPV Violating Supersymmetry

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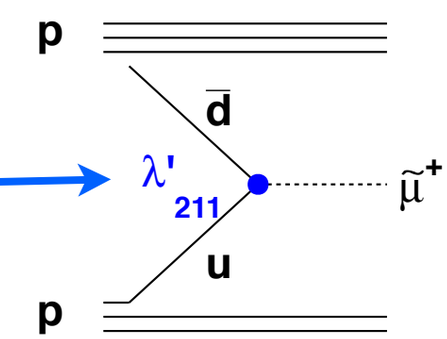
RPV SUSY Scope

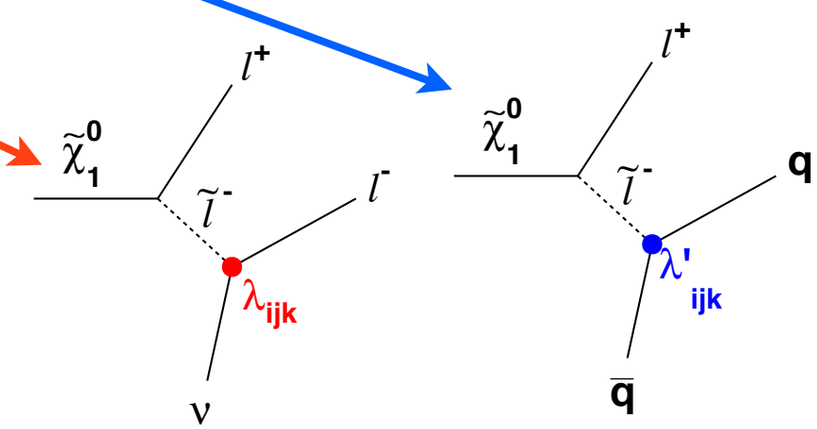
- SUSY classic assumes exact R-parity symmetry
  - stable LSP
    - dark matter candidate
    - experimental MET signatures
    - ...
- However SUSY Lagrangian allows R-parity violating (RPV) terms

$$W_{\Delta L=1} = \frac{1}{2}\lambda^{ijk} L_i L_j \bar{e}_k + \lambda'^{ijk} L_i Q_j \bar{d}_k + \mu'^{i} L_i H_u$$

$$W_{\Delta B=1} = \frac{1}{2}\lambda''^{ijk} \bar{u}_i \bar{d}_j \bar{d}_k$$

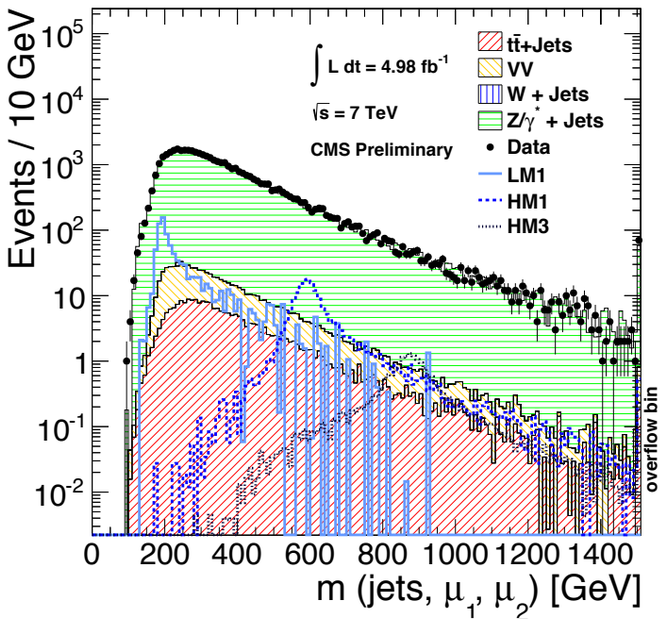


  - breaks lepton number, or baryon number
- Implications
  - resonant production of SUSY particles
  - unstable SUSY LSP
    - assume λ is big enough: cτ << 1mm

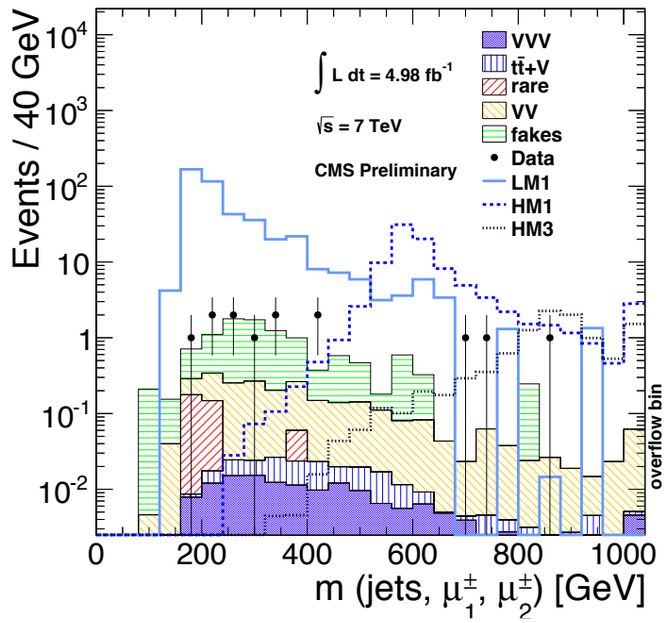


Search for Resonant Smuon Production

before selections

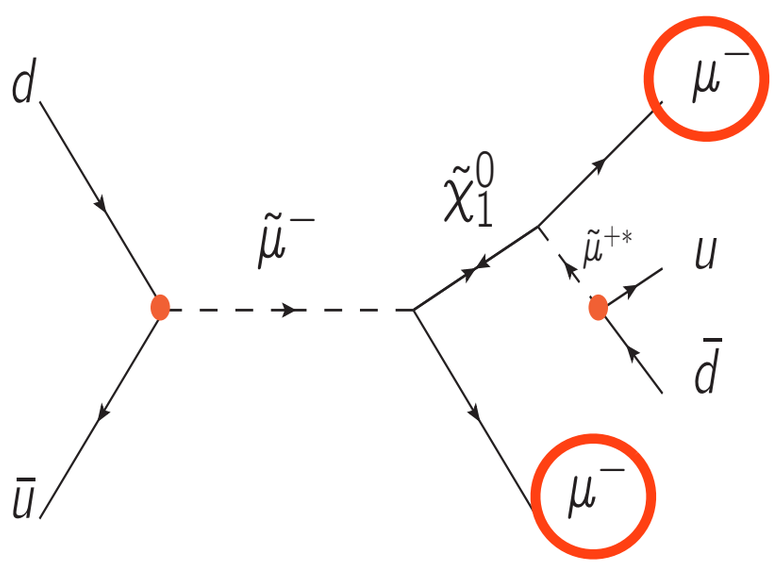


after selections

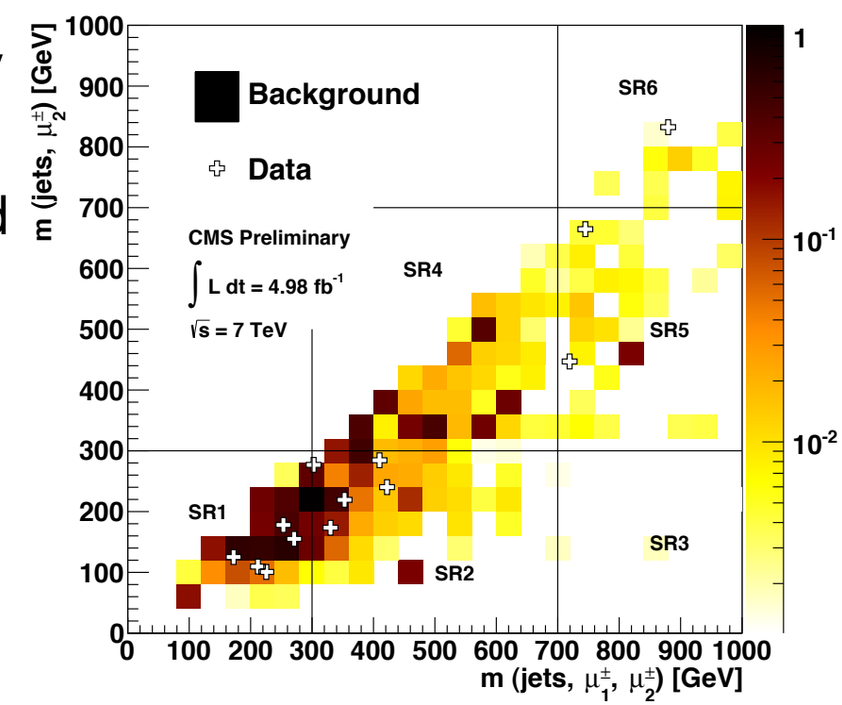


process	totals	SR1	SR2	SR3
VVV	0.15 ± 0.08	0.043 ± 0.022	0.054 ± 0.028	<0.001
tt+V	0.11 ± 0.06	0.019 ± 0.010	0.038 ± 0.020	0
rare	0.36 ± 0.26	0.32 ± 0.24	0.042 ± 0.042	<0.001
VV	2.1 ± 1.1	0.69 ± 0.35	0.68 ± 0.34	0.003 ± 0.002
fakes	8.2 ± 3.0	3.5 ± 1.6	1.9 ± 1.0	<0.001
Σ	10.9 ± 3.4	4.6 ± 1.6	2.7 ± 1.1	0.003 ± 0.002
data	13	5	5	0
95% C.L. limit on N_{sig}	11.3	6.9	8.0	2.8

process		SR4	SR5	SR6
VVV		0.036 ± 0.018	0.010 ± 0.005	0.007 ± 0.004
tt+V		0.044 ± 0.023	0.006 ± 0.004	0.006 ± 0.004
rare		<0.001	<0.001	<0.001
VV		0.49 ± 0.25	0.15 ± 0.08	0.093 ± 0.050
fakes		2.5 ± 1.2	0.22 ± 0.23	<0.001
Σ		3.1 ± 1.2	0.39 ± 0.25	0.11 ± 0.05
data		0	2	1
95% C.L. limit on N_{sig}		2.9	6.0	4.6



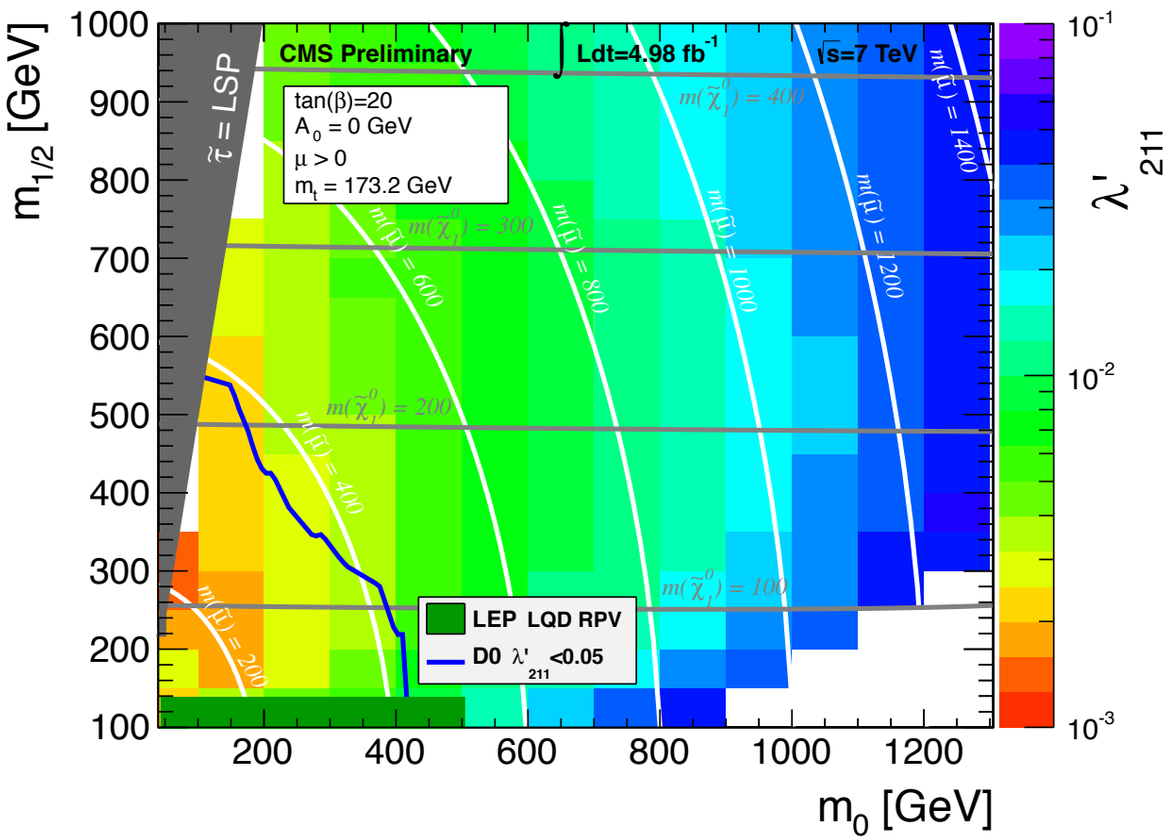
- Same-Sign prompt muon pairs, $p_T > 20/15$ GeV
- 2+ jets, $p_T > 30$ GeV
- Z veto, B-tag veto, MET < 50 GeV
- fake muons from heavy flavor is the primary remaining background
  - data driven estimation
- Expect resonance structure in both (μ,μ,jets) and (μ,jets) masses for the signal
  - split into regions in those variables
- Observations are consistent with background predictions

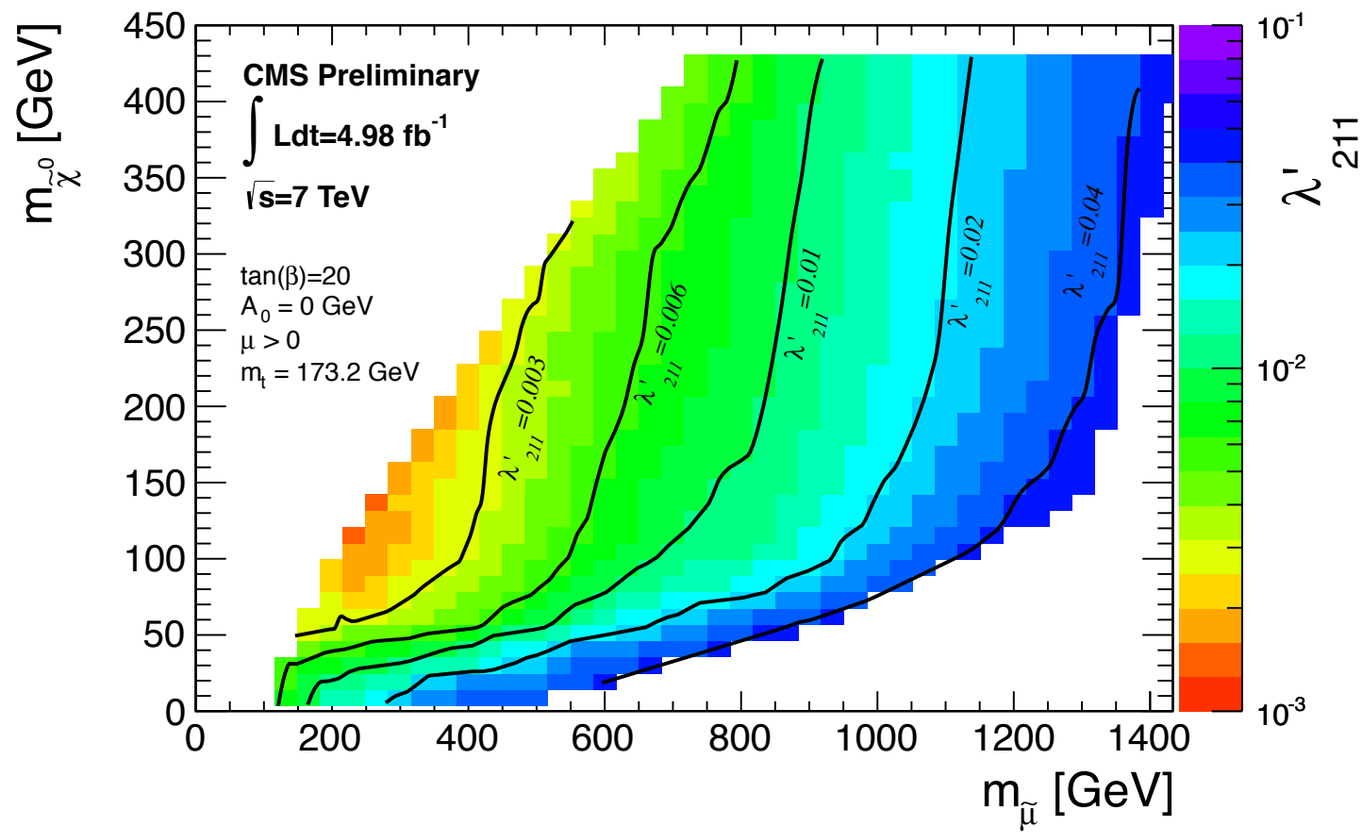


New Result!

CMS SUS-13-005

Implications for λ'_{211}



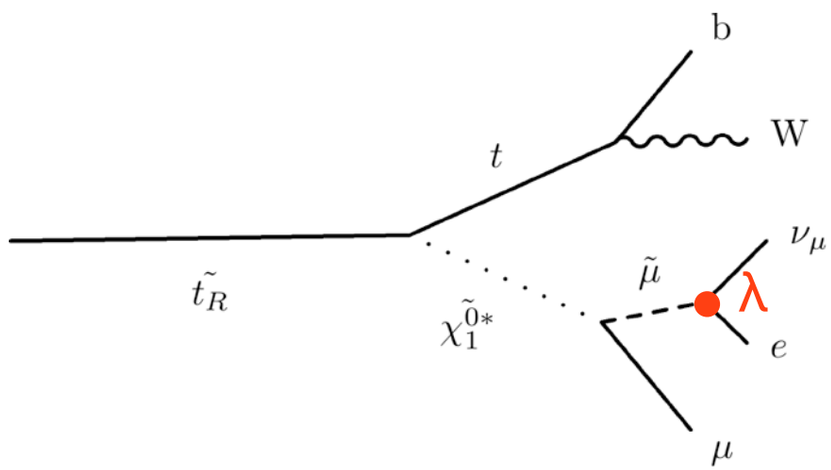


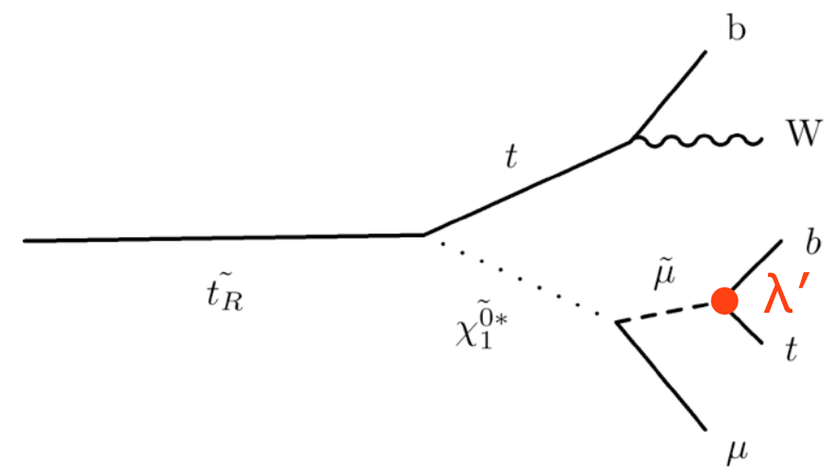
- Use cMSSM as an underlying RPC model
  - present λ'_{211} exclusion in both m_0:$m_{½}$ and $m_{neutralino}$:m_{smuon} planes
  - significantly extend previous exclusions

CMS SUS-13-005

Search for Unstable LSP

CMS SUS-13-003



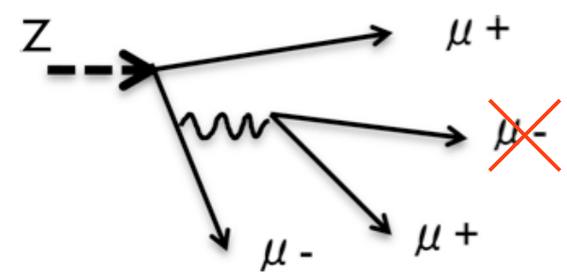


- Search for stop in RPV SUSY with multi-leptons and B-tag
  - 3, 4 leptons in the event: e, μ, ≤1 hadronic τ
  - 0, 1 B-tag in the event
  - no MET requirement (it is RPV search!)
  - binning in scalar sum of p_T for all reconstructed objects the event, S_T

Backgrounds and Observations

CMS SUS-13-003

- Irreducible backgrounds
  - from validated MC
- Asymmetric photon conversion
  - evaluate $l^+l^-l^\pm$ contribution from $l^+l^-\gamma$



- Light leptons fakes
  - Sophisticated data driven fake rate determination using tracks as reference objects
- Tau lepton fakes
  - Sophisticated data driven scaling of isolation sidebands to the signal region

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
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
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
3	0	116	123 ± 50	130	127 ± 54	13	18.9 ± 6.7	1	1.43 ± 0.51	0	0.208 ± 0.096
3	1	710	698 ± 287	746	837 ± 423	83	97 ± 48	3	6.9 ± 3.9	0	0.73 ± 0.49

  - data with B-tag and off-Z OSSF lepton pair in the event
  - data without B-tag are also used in high S_T regions
- Observations are consistent with background expectations

Interpretations

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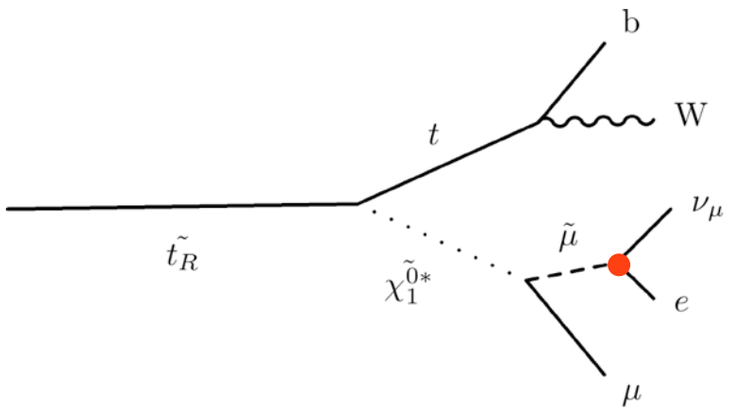
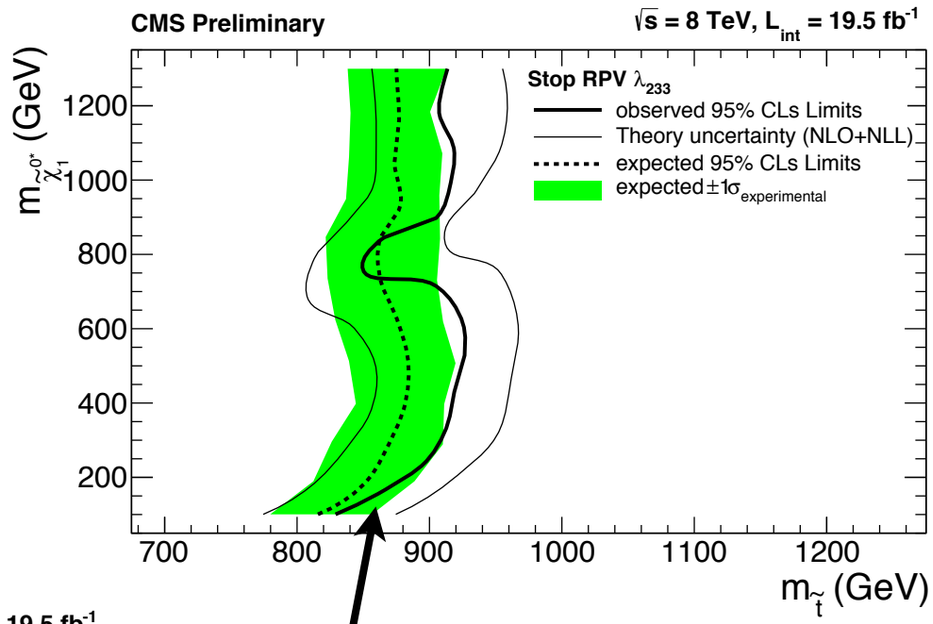
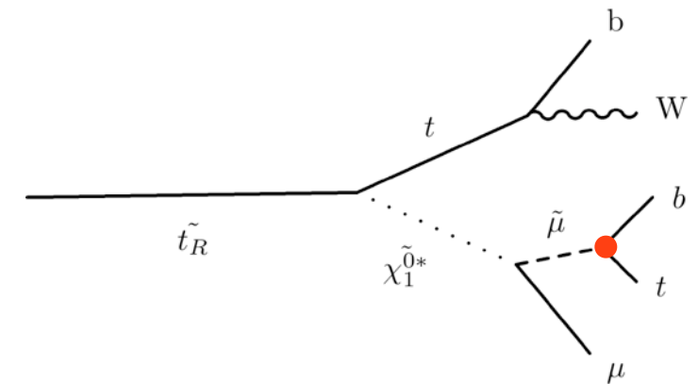
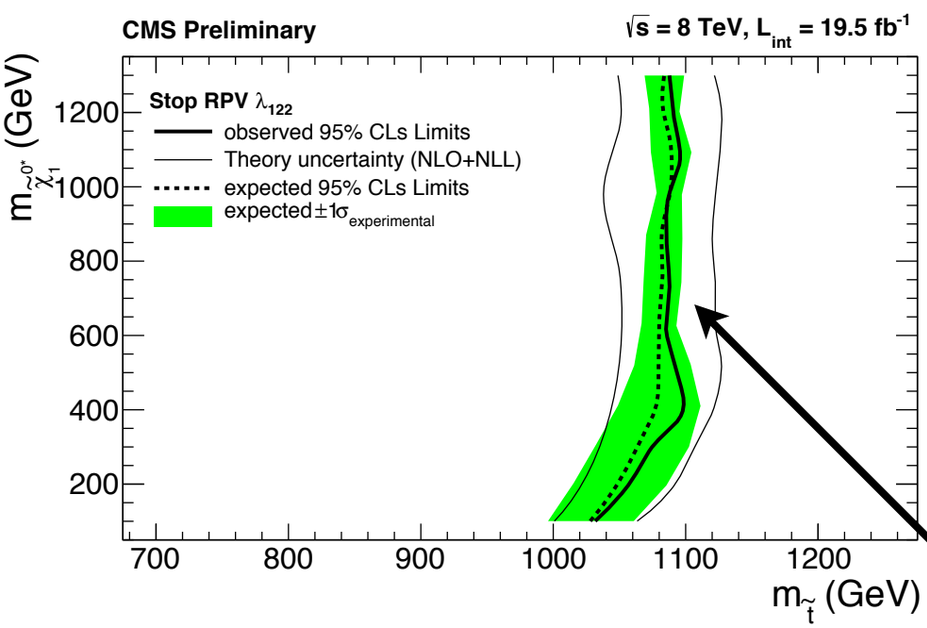
- Use Simplified models for stop production

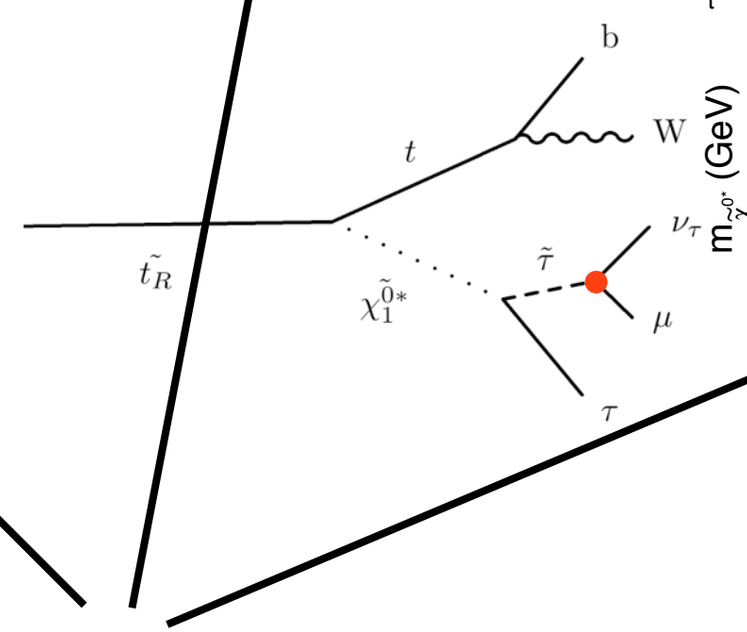


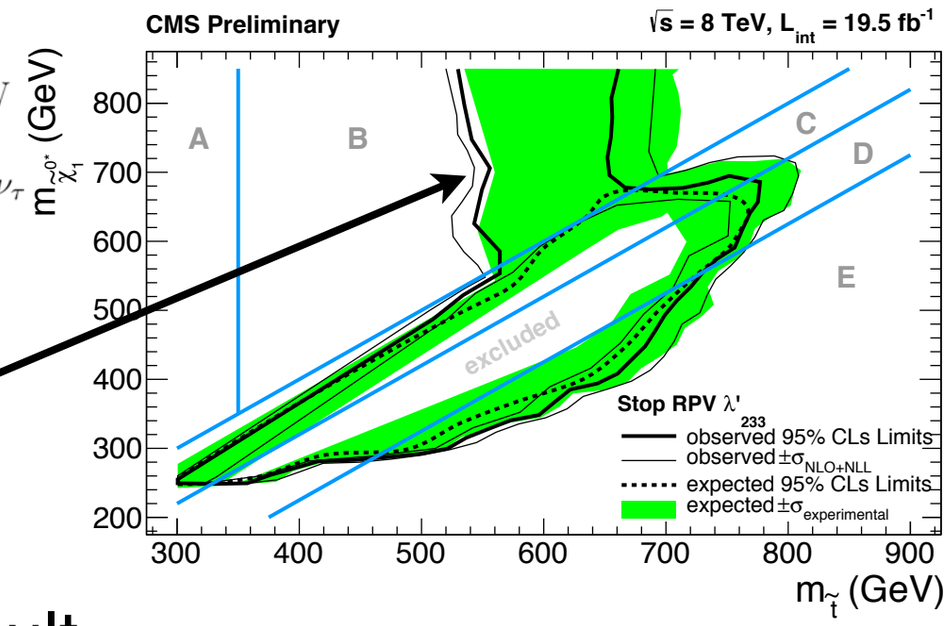




region label	kinematic region	stop decay mode(s)
A	$m_t < m_{\tilde{t}} < 2m_t, m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\nu\bar{b}$
B	$2m_t < m_{\tilde{t}} < m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\mu t\bar{b} + t\nu b\bar{b}$
C	$m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_W + m_{\tilde{\chi}_1^0}$	$\tilde{t}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







- Flat exclusions may be an indication of the result independence from the underlying SUSY dynamics

Generalization

- RPV SUSY model ≡ underlying RPC SUSY model + RPV term(s)
  - SUSY production is driven by the RPC component of the model
- RPV signature is an LSP decay signature
  - experimental signature is driven by LSP properties
- May decouple RPC and RPV components of the model
  - provided experimental RPV signature is not significantly affected by the RPC model component

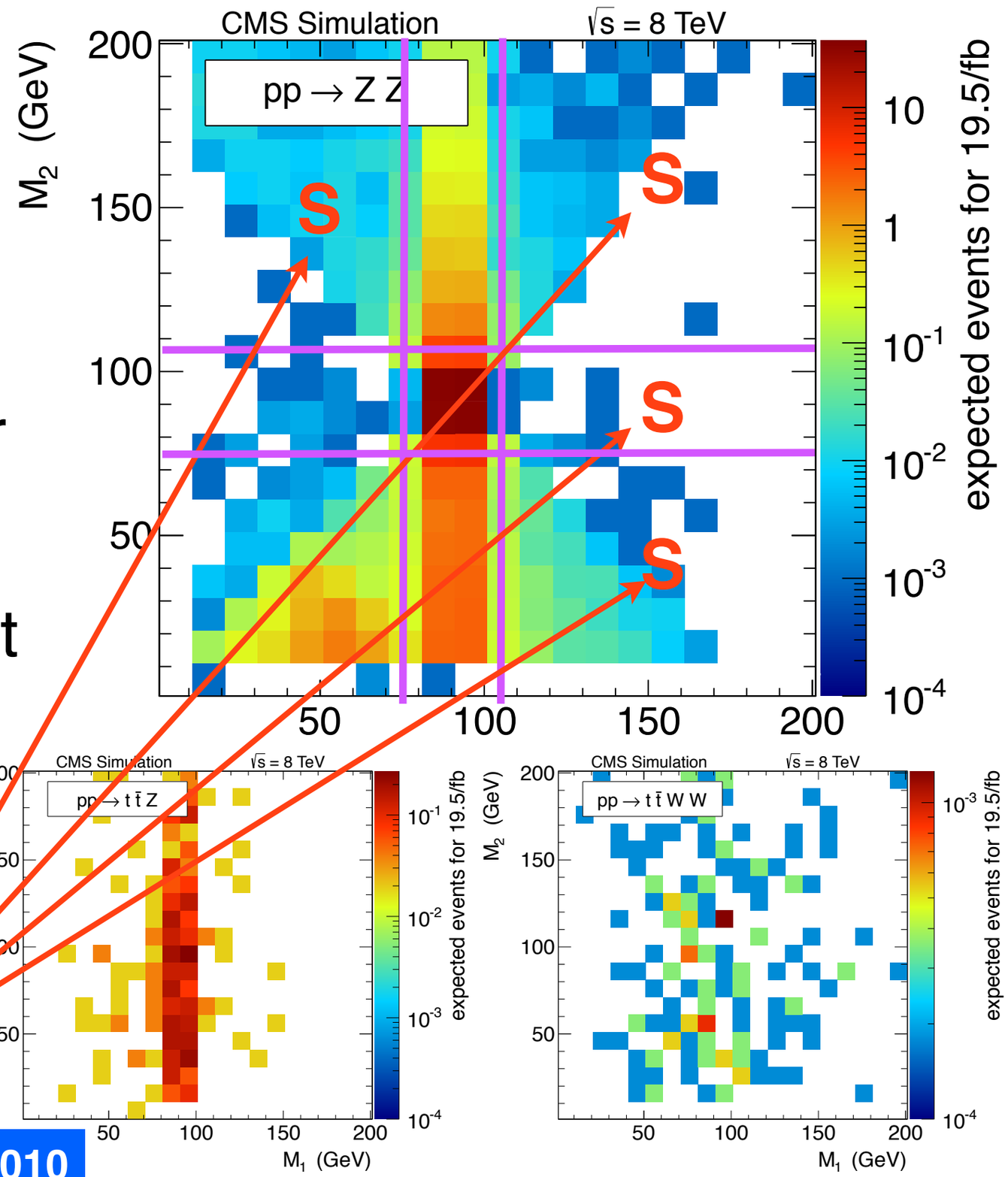
4-lepton Analysis

New Result! CMS SUS-13-010

- Presence of 4 isolated leptons in the event is alone a strong discriminant for SM processes
  - ZZ production is a main SM contribution
    - After suppressing ZZ, no more sophisticated selections are necessary
      - No MET, S_T, B-tag... - decouple underlying RPC SUSY component
- Leptons from LSP decays are usually hard
  - high ID efficiency is expected
- Need to prove quantitively
  - Impact of underlying RPC driven event component on the 4-lepton reconstruction efficiency

Search for Leptonic RPV in 4-lepton Events

- Select exactly 4-lepton events (e, μ)
- Loop over OSSF pairs, find closest to M_Z, call it M_1
- Another OS (OF or SF) pair gives M_2
- Plot events in M_2:M_1 2D plot
- OS mass regions
  - 0 - 75 - 105 - ∞ GeV
  - 9 analysis regions
  - 4 regions are combined into search region



CMS SUS-13-010

Backgrounds and Observations

		$M_1 < 75\ GeV$	$75 < M_1 < 105\ GeV$	$M_1 > 105\ GeV$
$M_2 > 105\ GeV$	ZZ	0.76±0.18	15±4	0.30±0.07
	rare	0.28±0.13	2.7±1.0	0.12±0.05
	fakes	0.4±0.4	0.7±0.7	0.05±0.05
	all backgrounds	1.4±0.5	18±4	0.47±0.10
	observed	0	20	0
$75 < M_2 < 105\ GeV$	ZZ	0.10±0.03	150*	0.05±0.01
	rare	0.12±0.05	2.5±1.2	0.06±0.03
	fakes	0.3±0.3	0.6±0.6	0.05±0.05
	all backgrounds	0.52±0.34	153*	0.16±0.06
	observed	0	160	0
$M_2 < 75\ GeV$	ZZ	9.8±2.0	32±8	0.98±0.20
	rare	0.31±0.14	2.5±1.2	0.011±0.005
	fakes	0.3±0.3	0.8±0.8	0.06±0.06
	all backgrounds	10.4±2.0	35±8	1.0±0.2
	observed	14	30	1

* ZZ prediction in "in Z":"in Z" region is based on MC normalized to CMS ZZ production cross section measurement, which is correlated with observation in "in Z":"in Z" region of this analysis.

- Backgrounds estimation
  - irreducible SM - from MC
  - fakes - data driven
- Observe 1 event in signal region (expect 3±0.6)
  - CLs upper limit on BSM contribution: 3.4 events

CMS SUS-13-010

Impact of RPC Underlying Event

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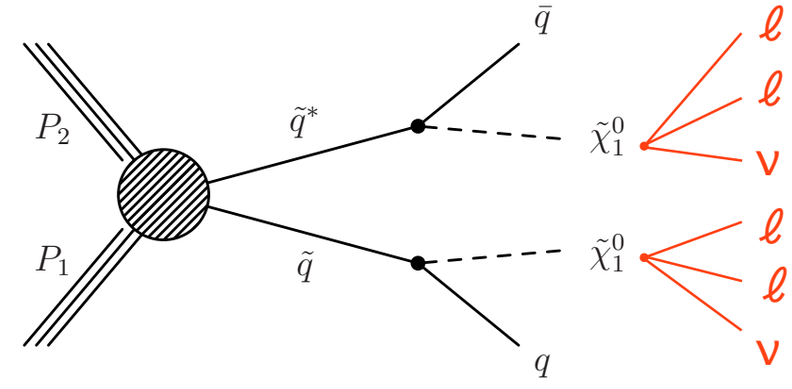
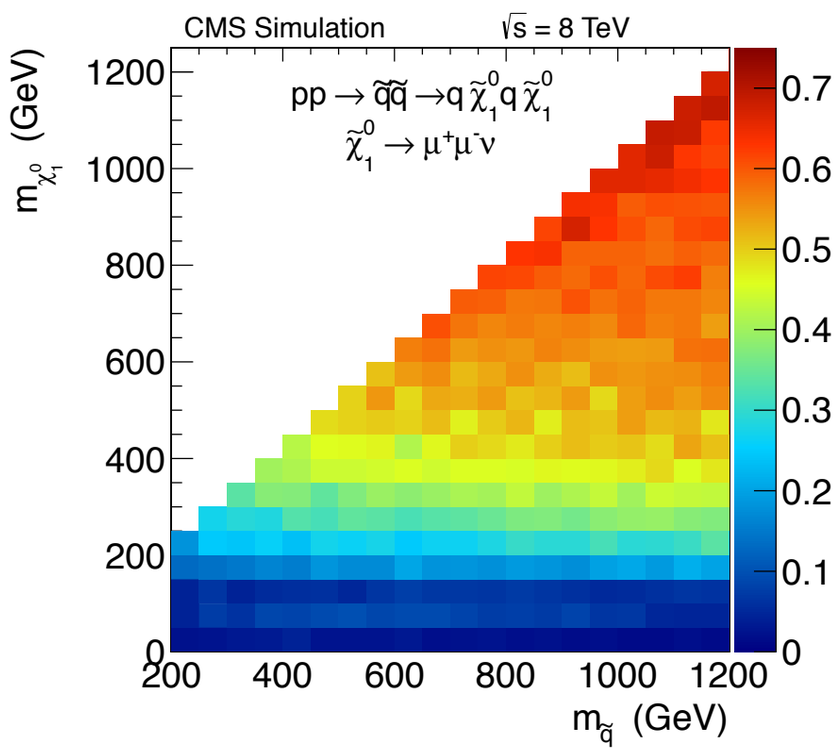
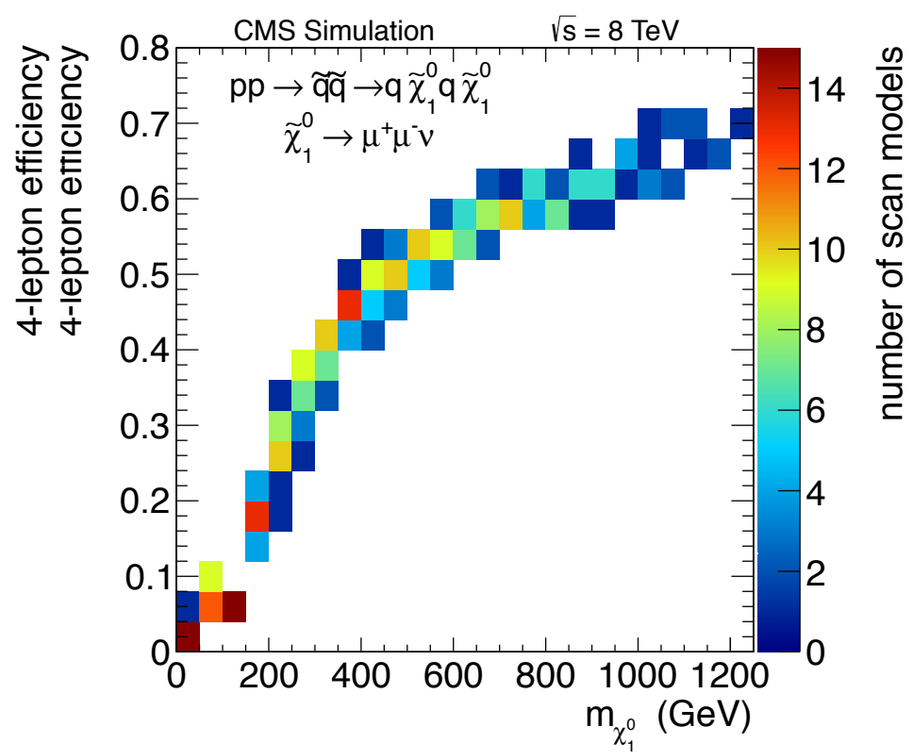
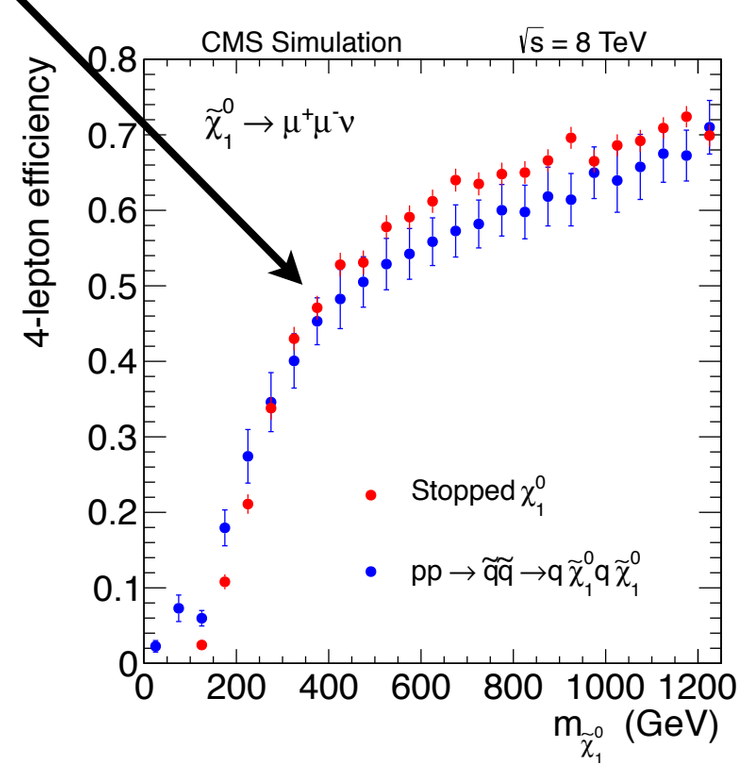
- Is 4-lepton efficiency affected by neutralino dynamics? No!
  - Consider two extreme cases
    - neutralino is produced in 2-body decay of directly produced squark
      - the most energetic neutralino
    - neutralino is produced in the rest
      - the most soft neutralino
  - Efficiency is driven by neutralino mass via signal region masses selection
  - No significant difference in efficiency for very hard and extremely soft neutralinos



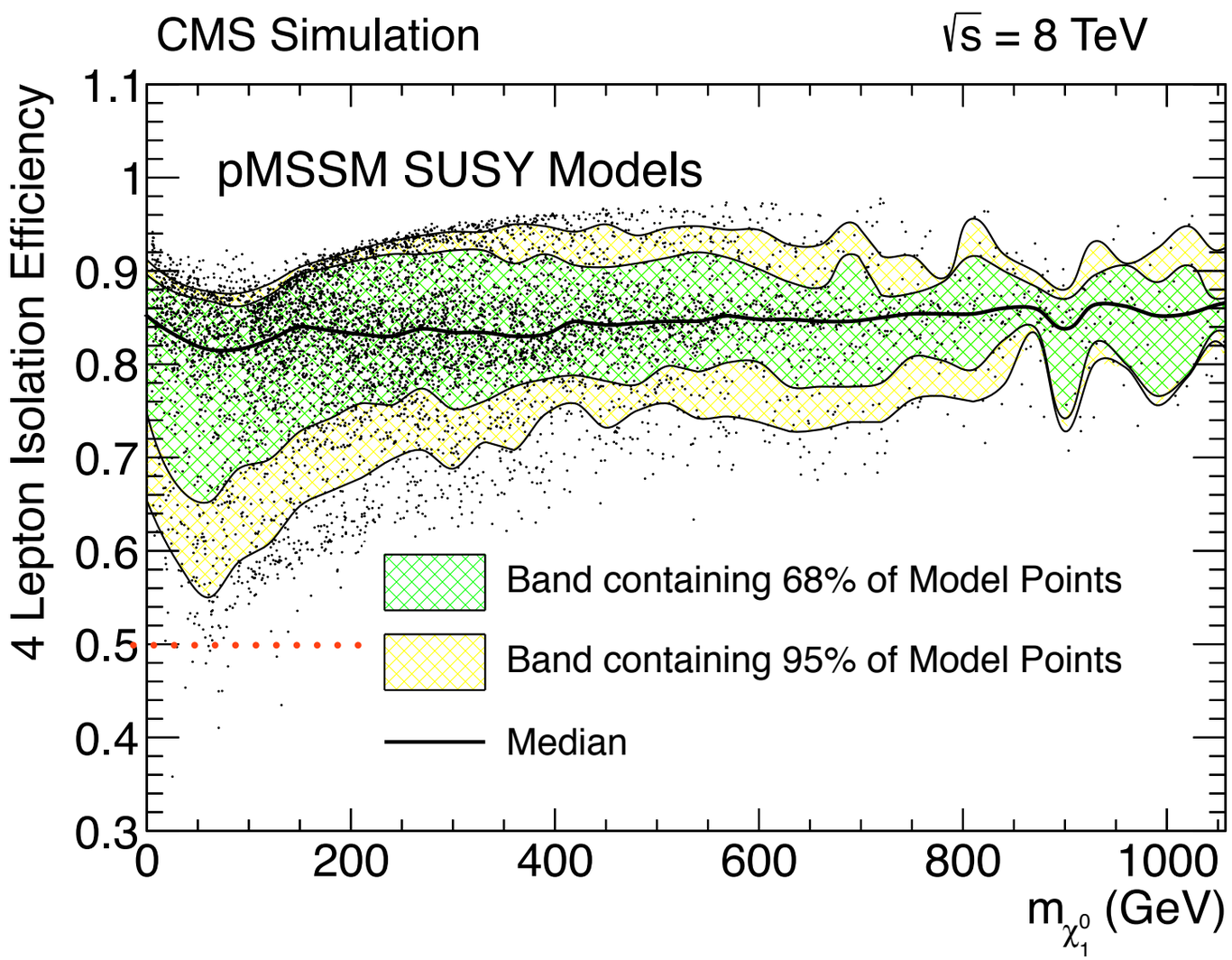






Impact of RPC Underlying Event

- Is 4-lepton efficiency affected by underlying event activity via lepton isolation? It is!
- Use sample ~7300 pMSSM models chosen with flat parameter priors at EWK scale
  - This set represents properties of generic MSSM
  - More details in: Lukas Vanelderen CMS SUS-12-030 poster #71@LHCP
- Emulate isolation around direction of the neutralino decay products



- Efficiency variations well fit a band [0.5, 1]

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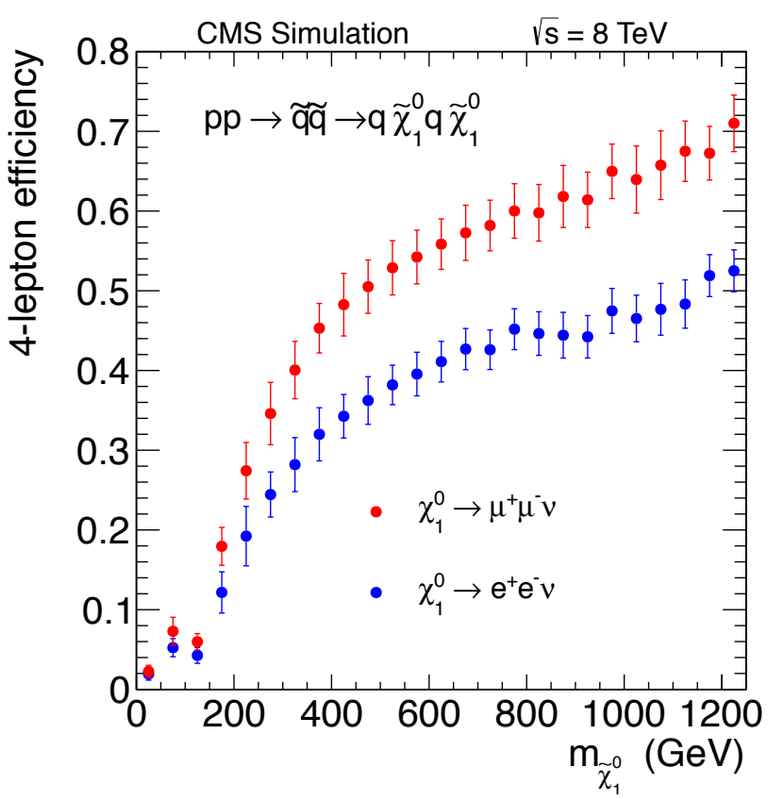
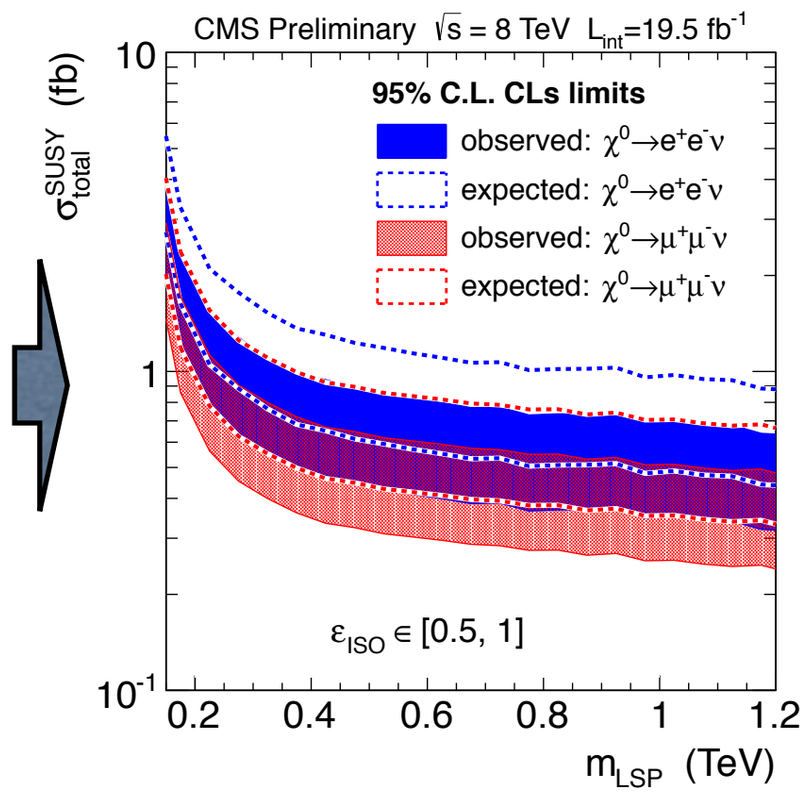
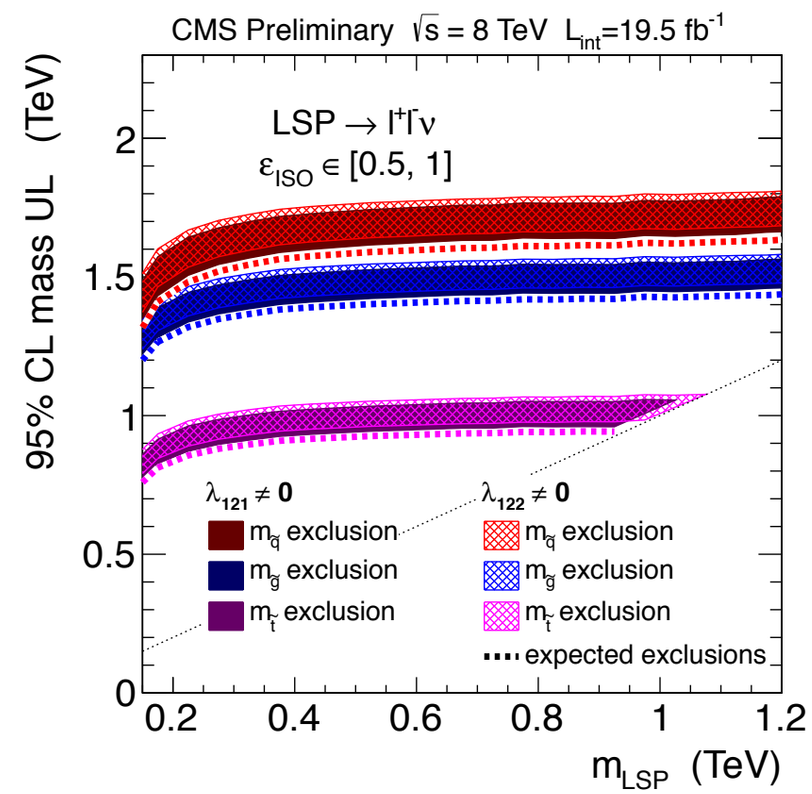
General Interpretation

- Identification and selection efficiency doesn't depend from neutralino dynamics
- Isolation efficiency may be bracketed by [0.5, 1] for general set of models







- The band in these results covers a wide range of underlying RPC MSSM SUSY physics models

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Conclusion

- CMS developed program for different RPV searches
- Searches for both resonant production of SUSY particles and for LSP decays
- Multi-lepton searches are sensitive not only to leptonic RPV term λ, but also to lepto-quark RPV term λ'_{i3k} via top leptonic signature
- RPV signatures may be decoupled from underlying RPC component of the SUSY model
  - Analysis results may be generalized
- Use set of pMSSM models to study impact of RPC model component on RPV term signature
  - Make results applicable to generic set of MSSM SUSY models