Taming the Landscape: RPV Signatures at the LHC

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Roadmap

- The RPV MSSM:
  Of Theorists' Dreams & Experimentalists' Nightmares
- Where We Are
- Where to?
- Outlook

The RPV MSSM

- Minimal SUSY: Poincare (+SUSY) invariance, SM gauge, MSSM content

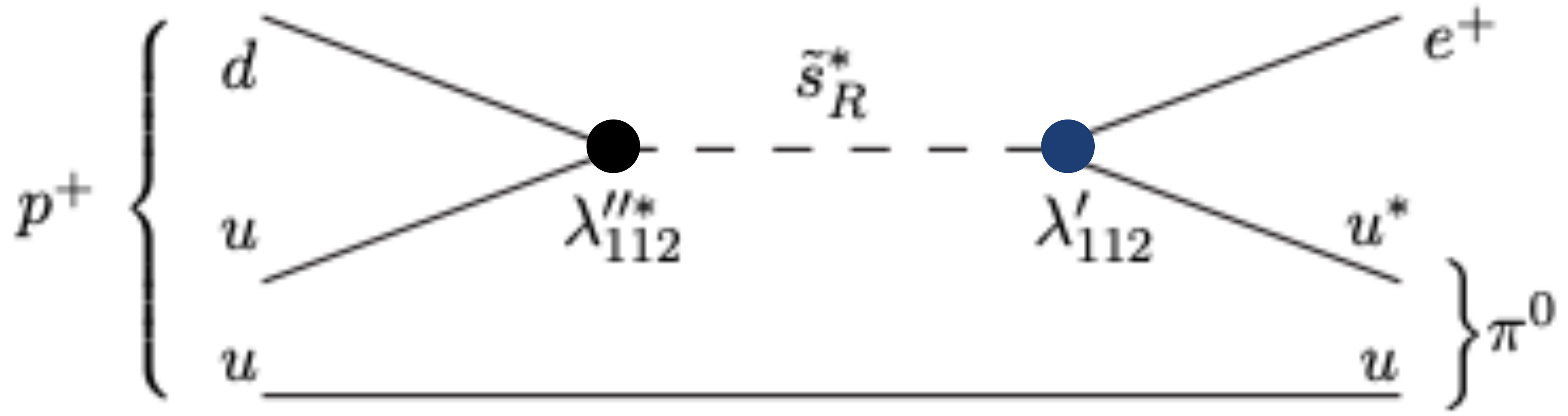
$$W = W_{\mathrm{MSSM}} + \lambda_{ijk}\, \mathrm{L}^i\mathrm{L}^j\mathrm{E}^k + \lambda'_{ijk}\, \mathrm{L}^i\mathrm{Q}^j\mathrm{D}^k + \kappa_i\, \mathrm{L}^i\mathrm{H}^d \quad \text{LNV}$$

$$+\lambda''_{ijk}\, \mathrm{U}^i\mathrm{D}^j\mathrm{D}^k \quad \text{BNV}$$

- LNV + BNV

Proton decay

Bound ~ 10^{34} yrs



The RPV MSSM

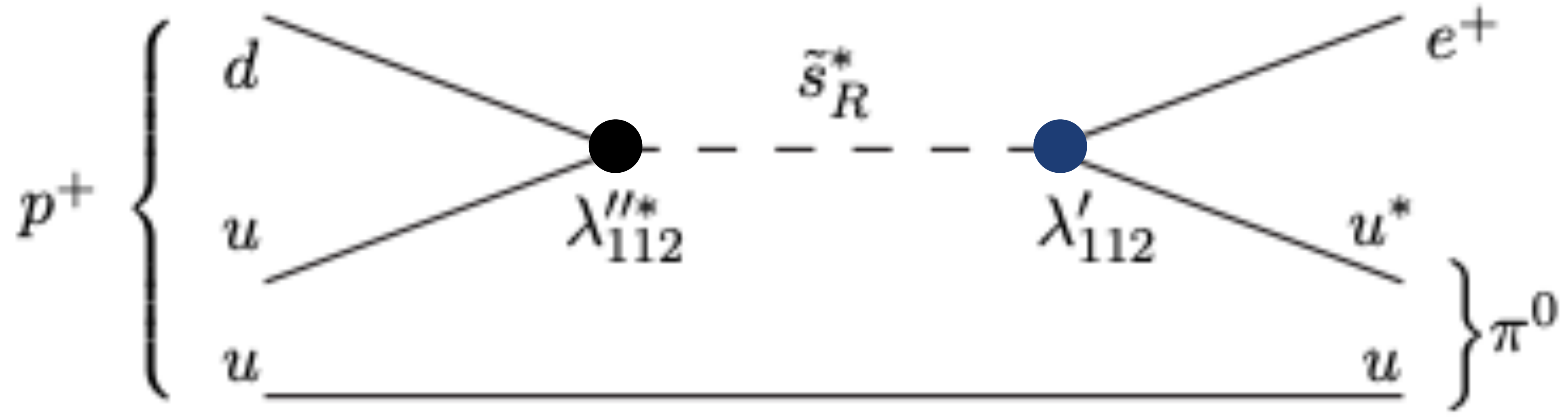
- MSSM: Impose *R*-parity

$$R = (-1)^{3(B-L)+2s} = \begin{cases} +1 \text{ for SM particles, higgses} \\ -1 \text{ for SUSY particles} \end{cases}$$

- $W = W_{\text{MSSM}} + W_{\text{LNV}} + W_{\text{BNV}}$ Proton stable! (@ tree-level)

The RPV MSSM

- But to protect the proton removing either ● or ● can be sufficient



- Indeed R is excessive! Baryon triality B_3 protects the proton (even better than R!)

$$W_{\mathrm{RPV}} = W_{\mathrm{MSSM}} + W_{\mathrm{LNV}} + W_{\mathrm{BNV}}$$

The RPV MSSM

Drastic changes RPV vs MSSM:

- Lightest SUSY particle (LSP) is stable -> no longer!

  (odd in R)

- LSP is neutralino -> no longer!

  (no longer DM candidate)

  LSP $\in \{\chi_1^0, \chi_1^+, \tilde{\nu}_L, \tilde{\ell}^{\pm}_{L,R}, \tilde{\tau}_1^{\pm}, \tilde{q}_{L,R}, \tilde{t}_1, \tilde{g}\}$

} SUSY signature no longer MET!

- Single SUSY production possible } Colliders can have 2x reach!

The RPV MSSM:
A Theorist's Dream

RPV has many nice features; all following from minimal SUSY:

- Ingredients for baryogenesis

- Ingredients for neutrino masses

- Ingredients for LFUV, muon (g-2), leptoquarks, etc.

- Playground for many new opportunities: lepton PDFs, Long Lived Particles, etc.

The RPV MSSM:
An Experimentalist's Nightmare

- Vanilla MSSM:

  SUSY pair production —> Decay to Neutralino LSP —> MET signature

- RPV SUSY:

$$\text{sig.} = \begin{pmatrix} \tilde{q}\tilde{q} \\ \tilde{q}\tilde{g} \\ \tilde{g}\tilde{g} \\ \tilde{\ell}^+\tilde{\ell}^- \\ \tilde{\nu}\tilde{\nu} \\ \tilde{\chi}^0\tilde{\chi}^\pm \end{pmatrix}_{\text{prod}} \otimes \begin{pmatrix} \tilde{\chi}_1^0 \\ \tilde{\chi}_1^\pm \\ \tilde{\nu}_i \\ \tilde{\ell}_i^\pm \\ \tilde{\tau} \\ \tilde{q} \\ \tilde{b} \\ \tilde{t} \\ \tilde{g} \end{pmatrix}_{\substack{\text{possible} \\ \text{LSP}}} \otimes \begin{pmatrix} L_1 L_2 \bar{E}_1 \\ \dots \\ L_1 Q_1 \bar{D}_1 \\ \dots \\ \bar{U}_3 \bar{D}_2 \bar{D}_3 \end{pmatrix}_{\substack{\text{LSP} \\ \text{decay}}}$$

45 couplings!

Where We Are

How well can we exclude SUSY?

Vanilla MSSM	RPV MSSM
-> Missing energy searches	-> ?
-> Coloured sector upto $\mathcal{O}$(TeV)	-> ?

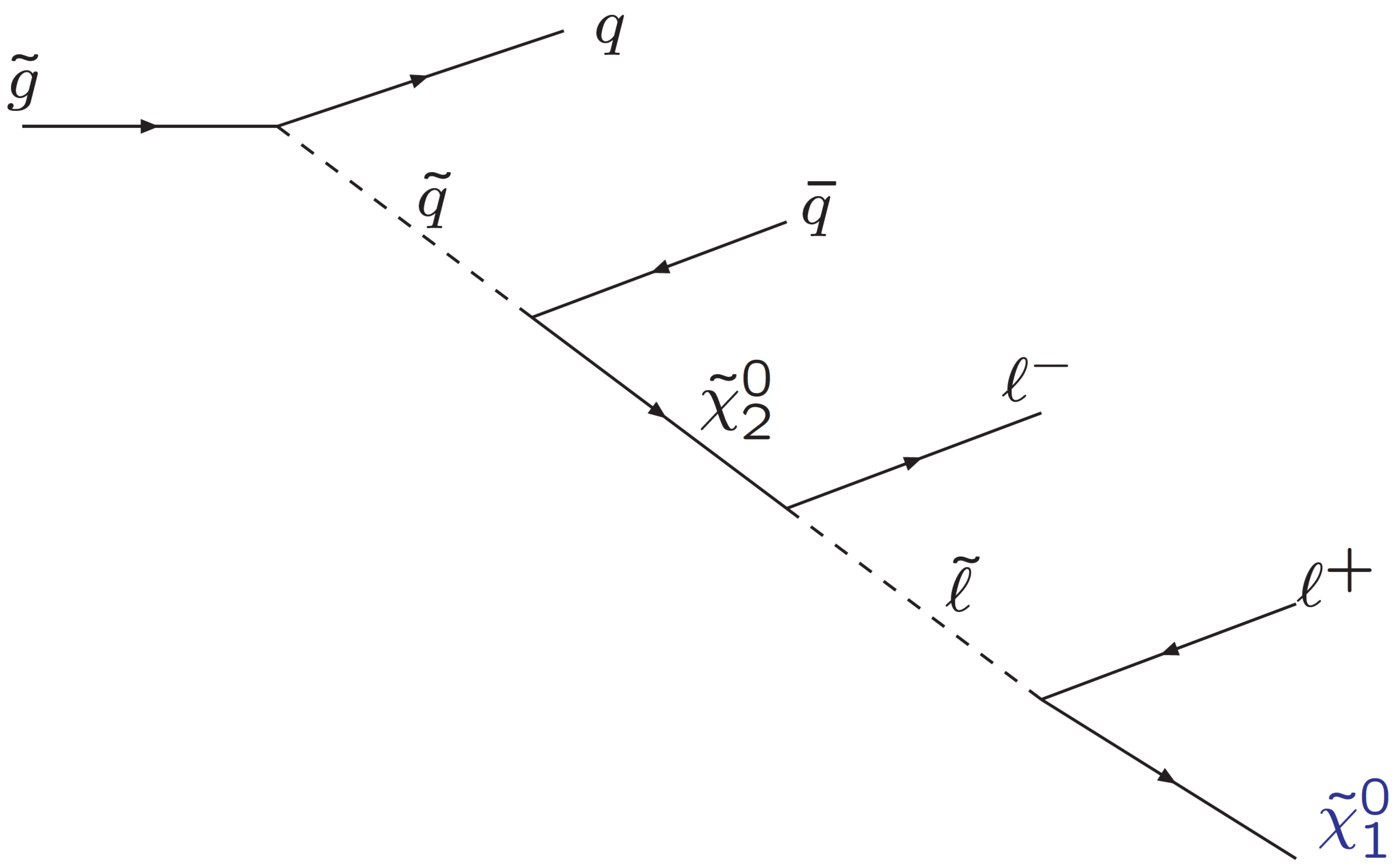
Have we systematically investigated RPV MSSM?

arXiv: 1706.09418 [Dreiner et al.]

Where We Are

Assumptions:

- SUSY particle —> Cascade to LSP —> RPV decay within detector



$$\sim \mathcal{O}(10^{-4}) << \lambda << g \sim \mathcal{O}(1)$$

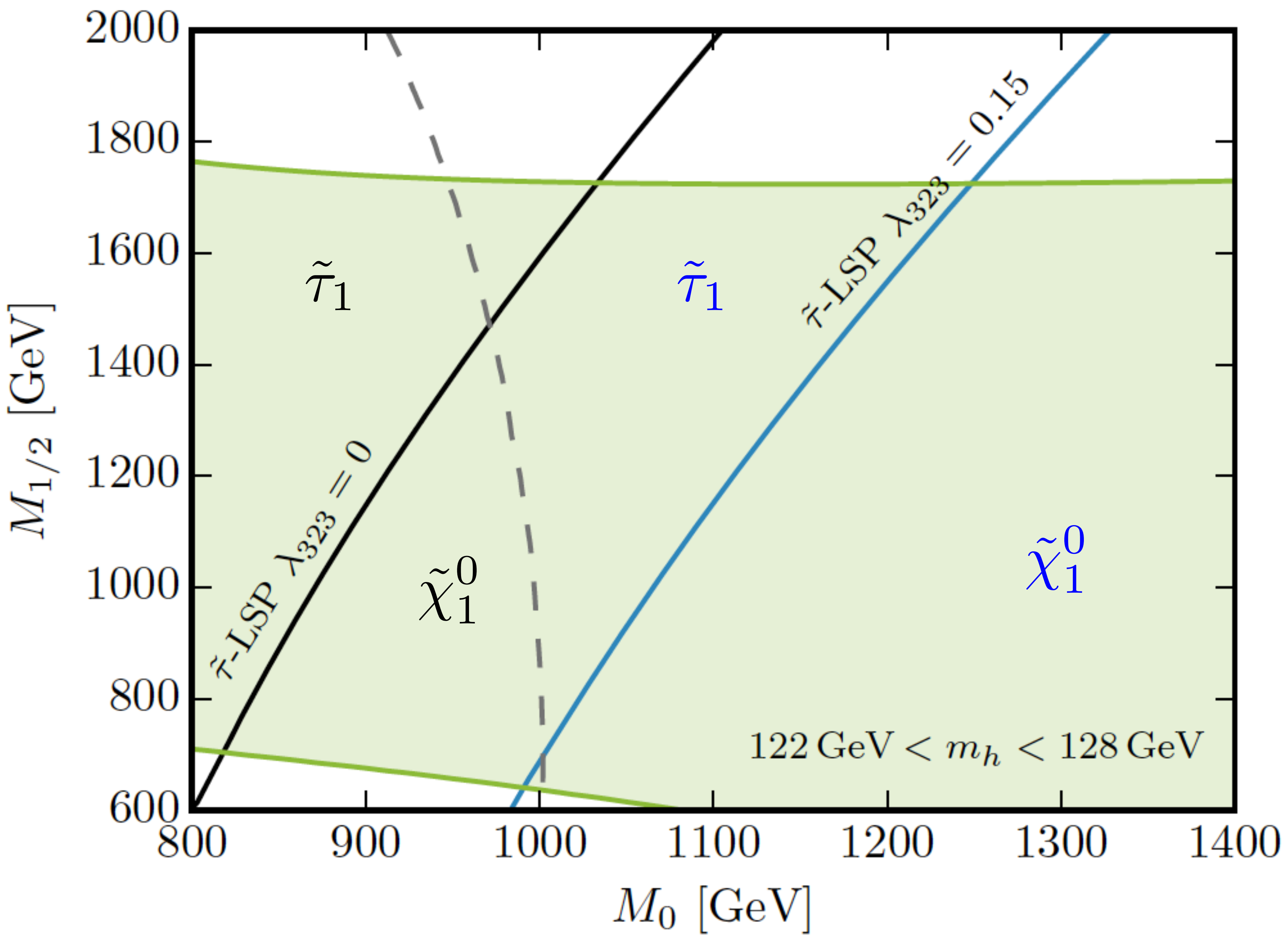
- No LLPs, no direct decays

Where We Are

Assumptions:

- Work in CMSSM
  Spectrum fixed by 5 parameters
  LSPs: $\tilde{\chi}_1^0$, $\tilde{\tau}$ mainly

LSP	Required Couplings
$\tilde{\chi}_1^0$	$\Lambda_{\not{R}_p} \ll 1$ or large M_0
$\tilde{\tau}_1$	$\Lambda_{\not{R}_p} \ll 1$, small M_0 and large $M_{1/2}$
$\tilde{\tau}_1$	λ_{ij3} (dominantly $\tilde{\tau}_R$), λ'_{3jk} ($\tilde{\tau}_L$)
$\tilde{e}_R$	λ_{ij1}
$\tilde{\mu}_R$	λ_{ij2}
$\tilde{\nu}_e$	λ'_{1jk} , $\{j,k\} \neq \{1,1\}^{\ddagger}$
$\tilde{\nu}_\mu$	λ'_{2jk}
$\tilde{s}_R, \tilde{d}_R$	λ''_{212} (degenerate LSPs)
$\tilde{b}_1$	λ''_{123}, λ''_{213}, $\lambda''_{223}{}^{\ddagger}$ (dominantly $\tilde{b}_R$)
$\tilde{t}_1$	λ''_{3jk} (dominantly $\tilde{t}_R$)



$$A_0 = -3\,\text{TeV}, \;\tan\beta = 30$$

Where We Are

Operators	LHC Signatures	Couplings
$LL\bar{E}$	$2\tau\, 4\ell\, \not{E}_T$	λ_{12c}
	$2\ell\, \not{E}_T$	$\lambda_{a3b,ab3,a33}$
	$\tau\, \ell\, \not{E}_T$	λ_{a33}
	$2\tau\, \not{E}_T$	λ_{a33}
$LQ\bar{D}$	4j $2\tau\, 2\ell$	λ'_{aij}
	4j $2\tau\, 1\ell\, \not{E}_T$	λ'_{aij}
	4j $2\tau\, \not{E}_T$	λ'_{aij}
	4j	λ'_{3ij}
$\bar{U}\bar{D}\bar{D}$	6j 2τ	λ''_{ijk}
	6j $\not{E}_T$	λ''_{3jk} ‡

Main take away message:

- Can reduce RPV scenarios to set of few signatures
- Used this to identify gaps: Few in $\tilde{\chi}_0^1$ case; more in $\tilde{\tau}$
- Recast existing searches to cover gaps: RPV coverage is comparable to RPC for CMSSM!

Where to?

Can we come up with minimal set of signatures to cover RPV SUSY generally?

Assumptions:

- SUSY particle —> Cascade to LSP —> RPV decay within detector

- ~~Work in CMSSM~~
  ~~Spectrum fixed by 5 parameters~~
  ~~LSPs: $\tilde{\chi}_1^0$, $\tilde{\tau}$ mainly~~

} Allow more general models

Blind to spectrum

Where to?

Blind to spectrum

- Any particle can be LSP -> many more scenarios to consider!

- Blind to mass ordering -> even more permutations for a given scenario!

{LSP, coupling} $= \{\tilde{q}\,, \lambda''_{312}\}$

$\tilde{q}$:

$$\tilde{B} + j \to \tilde{H} + \nu + j \to \tilde{t} + \nu + t + j \to \nu + t + 3j$$

$$\tilde{g} + j \to \tilde{t} + t + j \to t + 3j$$

$$\tilde{g} + j \to \tilde{d} + 2j \to t + 3j$$

$$\tilde{B} + j \to \tilde{t} + t + j \to t + 3j$$

$$\tilde{B} + j \to \tilde{d} + 2j \to t + 3j$$

$t + 3j$

Where to?

LSP	LLE (I)	LL$_3$E (II)	LLE$_3$ (III)	LL$_3$E$_3$ (IV)
$\tilde{l}\,(\tilde{\nu})$	$(3l + E_T^{miss})$ / $4l$	$(2l + 1\tau + E_T^{miss})$ / $(2l + 2\tau)$	$(1l + 2\tau + E_T^{miss})$/$(2l + 2\tau)$	$(3\tau + E_T^{miss})$/4τ
$\tilde{e}$	$(2l + E_T^{miss})$	$(2l + E_T^{miss})/(1l + 1\tau + E_T^{miss})$	$4l + 2\tau + E_T^{miss}$	$(4l + 2\tau + E_T^{miss})/(3l + 3\tau + E_T^{miss})$
$\tilde{\tau}\,(\tilde{\nu}_\tau)$	$(4l + 2\tau + E_T^{miss})$ / $(4l + 1\tau + E_T^{miss})$	$(3l + E_T^{miss})$/$4l$	$(2l + 4\tau + E_T^{miss})$ / $(2l + 3\tau + E_T^{miss})$	$(2l + 2\tau)$ / $(1l + 2\tau + E_T^{miss})$
$\tilde{\tau}_R$	$4l + 2\tau + E_T^{miss}$	$(4l + 2\tau + E_T^{miss})/3l + 3\tau + E_T^{miss})$	$2l + E_T^{miss}$	$(2l + E_T^{miss})/(1l + 1\tau + E_T^{miss})$
$\tilde{g}$	$4l + 4J + E_T^{miss}$	$(4l + 4J + E_T^{miss})/(3l + 1\tau + 4J + E_T^{miss})$	$2l + 2\tau + 4J + E_T^{miss}$	$(2l + 2\tau + 4J + E_T^{miss})/(1l + 3\tau + 4J + E_T^{miss})$
$\tilde{q}/\tilde{u}/\tilde{d}$	$4l + 2j_l + E_T^{miss}$	$(4l + 2j_l + E_T^{miss})/(3l + 1\tau + 2j_l + E_T^{miss})$	$2l + 2\tau + 2j_l + E_T^{miss}$	$(2l + 2\tau + 2j_l + E_T^{miss})/(1l + 3\tau + 2j_l + E_T^{miss})$
$\tilde{t}_L(\tilde{b}_L)/\tilde{t}_R$	$(4l + 2j_3 + E_T^{miss})$	$(4l + 2j_3 + E_T^{miss})/(3l + 1\tau + 2j_3 + E_T^{miss})$	$(2l + 2\tau + 2j_3 + E_T^{miss})$	$(2l + 2\tau + 2j_3 + E_T^{miss})/(1l + 3\tau + 2j_3 + E_T^{miss})$
$\tilde{b}_R$	$(4l + 2b + E_T^{miss})$	$(4l + 2b + E_T^{miss})/(3l + 1\tau + 2b + E_T^{miss})$	$2l + 2\tau + 2b + E_T^{miss}$	$(2l + 2\tau + 2b + E_T^{miss})/(1l + 3\tau + 2b + E_T^{miss})$
$\tilde{B}/\tilde{W}/\tilde{H}$	$4l + E_T^{miss}$	$(4l + E_T^{miss})/(3l + 1\tau + E_T^{miss})$	$2l + 2\tau + E_T^{miss}$	$(2l + 2\tau + E_T^{miss})/(1l + 3\tau + E_T^{miss})$

- l: e/μ
- L: $e/\mu/\tau$
- j_l: light jet
- b: bottom jet
- t: top jet
- j_3: b/t
- J: j_l/j_3

1. Four leptons 1: $4L + E_T^{miss}$ (- or + 2J or +4J)
2. Four leptons 2: $4L$
3. Two leptons: $2L + E_T^{miss}$
4. Three leptons: $3L + E_T^{miss}$
5. Five leptons: $5L + E_T^{miss}$
6. Six leptons: $6L + E_T^{miss}$

Where to?

Assumptions

LSP	LLE (I)	LL_3E (II)	LLE_3 (III)	LL_3E_3 (IV)
$\tilde{l}\,(\tilde{\nu})$	$(3l + E_T^{miss})$ / $4l$	$(2l + 1\tau + E_T^{miss})$ / $(2l + 2\tau)$	$(1l + 2\tau + E_T^{miss})$/ $(2l + 2\tau)$	$(3\tau + E_T^{miss})$/ 4τ
$\tilde{e}$	$(\mathbf{2l + E_T^{miss}})$	$(\mathbf{2l + E_T^{miss}})/(\mathbf{1l + 1\tau + E_T^{miss}})$	$\mathbf{4l + 2\tau + E_T^{miss}}$	$(\mathbf{4l + 2\tau + E_T^{miss}})/(\mathbf{3l + 3\tau + E_T^{miss}})$
$\tilde{\tau}\,(\tilde{\nu}_\tau)$	$(4l + 2\tau + E_T^{miss})$ / $(4l + 1\tau + E_T^{miss})$	$(3l + E_T^{miss})$/ $4l$	$(2l + 4\tau + E_T^{miss})$ / $(2l + 3\tau + E_T^{miss})$	$(2l + 2\tau)$ / $(1l + 2\tau + E_T^{miss})$
$\tilde{\tau}_R$	$\mathbf{4l + 2\tau + E_T^{miss}}$	$(\mathbf{4l + 2\tau + E_T^{miss}})/\mathbf{3l + 3\tau + E_T^{miss}})$	$\mathbf{2l + E_T^{miss}}$	$(\mathbf{2l + E_T^{miss}})/(\mathbf{1l + 1\tau + E_T^{miss}})$
$\tilde{g}$	$\mathbf{4l + 4J + E_T^{miss}}$	$(\mathbf{4l + 4J + E_T^{miss}})/(\mathbf{3l + 1\tau + 4J + E_T^{miss}})$	$\mathbf{2l + 2\tau + 4J + E_T^{miss}}$	$(\mathbf{2l + 2\tau + 4J + E_T^{miss}})/(\mathbf{1l + 3\tau + 4J + E_T^{miss}})$
$\tilde{q}/\tilde{u}/\tilde{d}$	$\mathbf{4l + 2j_l + E_T^{miss}}$	$(\mathbf{4l + 2j_l + E_T^{miss}})/(\mathbf{3l + 1\tau + 2j_l + E_T^{miss}})$	$\mathbf{2l + 2\tau + 2j_l + E_T^{miss}}$	$(\mathbf{2l + 2\tau + 2j_l + E_T^{miss}})/(\mathbf{1l + 3\tau + 2j_l + E_T^{miss}})$
$\tilde{t}_L(\tilde{b}_L)/\tilde{t}_R$	$(\mathbf{4l + 2j_3 + E_T^{miss}})$	$(\mathbf{4l + 2j_3 + E_T^{miss}})/(\mathbf{3l + 1\tau + 2j_3 + E_T^{miss}})$	$(\mathbf{2l + 2\tau + 2j_3 + E_T^{miss}})$	$(\mathbf{2l + 2\tau + 2j_3 + E_T^{miss}})/(\mathbf{1l + 3\tau + 2j_3 + E_T^{miss}})$
$\tilde{b}_R$	$(\mathbf{4l + 2b + E_T^{miss}})$	$(\mathbf{4l + 2b + E_T^{miss}})/(\mathbf{3l + 1\tau + 2b + E_T^{miss}})$	$\mathbf{2l + 2\tau + 2b + E_T^{miss}}$	$(\mathbf{2l + 2\tau + 2b + E_T^{miss}})/(\mathbf{1l + 3\tau + 2b + E_T^{miss}})$
$\tilde{B}/\tilde{W}/\tilde{H}$	$\mathbf{4l + E_T^{miss}}$	$(\mathbf{4l + E_T^{miss}})/(\mathbf{3l + 1\tau + E_T^{miss}})$	$\mathbf{2l + 2\tau + E_T^{miss}}$	$(\mathbf{2l + 2\tau + E_T^{miss}})/(\mathbf{1l + 3\tau + E_T^{miss}})$

- SU(2) doublets mass degenerate
- When equally likely, prefer signal with most l
- Also give alternate signatures that may have higher cross-sections

Where to?

LSP	UDD (I)	UD_3D (II)	U_3DD (III)	U_3D_3D (IV)
$\tilde{l}\,(\tilde{\nu})$	$(2l+6j_l)$ / $(1l+6j_l+E_T^{miss})$	$(2l+2b+4j_l)$ / $(1l+2b+4j_l+E_T^{miss})$	$(2l+2j_3+4j_l)$ / $(1l+2j_3+4j_l+E_T^{miss})$	$(2l+2j_3+2b+2j_l)$ / $(1l+2j_3+2b+2j_l+E_T^{miss})$
$/\tilde{e}$	$(2l+6j_l)$	$(2l+2b+4j_l)$	$(2l+2j_3+4j_l)$	$(2l+2j_3+2b+2j_l)$
$\tilde{\tau}\,(\tilde{\nu}_\tau)$	$(2\tau+6j_l)$ / $(1\tau+6j_l+E_T^{miss})$	$(2\tau+2b+4j_l)$ / $(1\tau+2b+4j_l+E_T^{miss})$	$(2\tau+2j_3+4j_l)$ / $(1\tau+2j_3+4j_l+E_T^{miss})$	$(2\tau+2j_3+2b+2j_l)$ / $(1\tau+2j_3+2b+2j_l+E_T^{miss})$
$\tilde{\tau}_R$	$(2\tau+6j_l)$	$(2\tau+2b+4j_l)$	$(2\tau+2j_3+4j_l)$	$(2\tau+2j_3+2b+2j_l)$
$\tilde{g}$	$6j_l$	$2b+4j_l$	$2t+4j_l$	$2t+2b+2j_l$
$\tilde{q}$	$8j_l$	$2b+6j_l$	$2t+6j_l$	$2t+2b+4j_l$
$\tilde{u}$	$4j_l$	$2b+2j_l$	$2t+6j_l$	$2t+2b+4j_l$
$\tilde{d}$	$4j_l$	$2b+2j_l$	$2t+2j_l$	$2t+2b$
$\tilde{t}_L\,(\tilde{b}_L)$	$(2j_3+6j_l)$	$2j_3+2b+4j_l$	$(4j_3+4j_l)$	$(4j_3+2b+2j_l)$
$\tilde{t}_R$	$2j_3+6j_l$	$2j_3+2b+4j_l$	$4j_l$	$2b+2j_l$
$\tilde{b}_R$	$2b+6j_l$	$4j_l$	$2j_3+2b+4j_l$	$2j_3+2j_l$
$\tilde{B}/\tilde{W}/\tilde{H}$	$6j_l$	$2b+4j_l$	$(2j_3+4j_l)$	$(2j_3+2b+2j_l)$

- l: e/μ
- L: $e/\mu/\tau$
- j_l: light jet
- b: bottom jet
- t: top jet
- j_3: b/t
- J: j_l/j_3

1. Two lepton: $2L+6J$
2. One lepton: $1L+6J+E_T^{miss}$
3. Zero lepton 1: $8J$
4. Zero lepton 2: $6J$
5. Zero lepton 3: $4J$

Where to?

LSP	LQD (I)	$\mathrm{LQD_3}$ (II)	$\mathrm{LQ_3D}$ (III)	$\mathrm{LQ_3D_3}$ (IV)
$\tilde{l}\,(\tilde{\nu})$	$\mathbf{4j_l}$	$\mathbf{2b + 2j_l}$	$\mathbf{(2j_3 + 2j_l)}$	$\mathbf{(2b + 2j_3)}$
$\tilde{e}$	$(4l + 4j_l)$ / $(3l + 4j_l + E_T^{miss})$	$(4l + 2j_l + 2b)$ / $(3l + 2j_l + 2b + E_T^{miss})$	$(4l + 2j_l + 2t)$ / $(3l + 2j_l + t + b + E_T^{miss})$ / $(2l + 2j_l + 2b + E_T^{miss})$	$(4l + 2t + 2b)$ / $(3l + t + 3b + E_T^{miss})$ / $(2l + 4b + E_T^{miss})$
$\tilde{\tau}\,(\tilde{\nu}_\tau)$	$(2l + 2\tau + 4j_l)$ / $(2l + 1\tau + 4j_l + E_T^{miss})$	$(2l + 2\tau + 2j_l + 2b)$ / $(2l + 1\tau + 2j_l + 2b + E_T^{miss})$	$(2l + 2\tau + 2t + 2j_l)$ / $(2l + 1\tau + 2t + 2j_l + E_T^{miss})$ / $(2\tau + 2b + 2j_l + E_T^{miss})$ / $(\tau + 2b + 2j_l + E_T^{miss})$	$(2l + 2\tau + 2t + 2b)$ / $(2l + 1\tau + 2t + 2b + E_T^{miss})$ / $(2\tau + 4b + E_T^{miss})$ / $(\tau + 4b + E_T^{miss})$
$\tilde{\tau}_R$	$(2l + 2\tau + 4j_l)$ / $(1l + 2\tau + 4j_l + E_T^{miss})$	$(2l + 2\tau + 2j_l + 2b)$ / $(1l + 2\tau + 2j_l + 2b + E_T^{miss})$	$(2l + 2\tau + 2j_l + 2t)$ / $(1l + 2\tau + 2j_l + t + b + E_T^{miss})$ / $(2\tau + 2j_l + 2b + E_T^{miss})$	$(2l + 2\tau + 2t + 2b)$ / $(1l + 2\tau + t + 3b + E_T^{miss})$ / $(2\tau + 4b + E_T^{miss})$
$\tilde{g}$	$(2l + 4j_l)$ / $(l + E_T^{miss} + 4j_l)$	$(2l + 2j_l + 2b)$ / $(l + E_T^{miss} + 2j_l + 2b)$	$(2l + 2j_l + 2t)$ / $(l + E_T^{miss} + 2j_l + t + b)$	$(2l + 2b + 2t)$ / $(l + E_T^{miss} + 3b + t)$
$\tilde{q}$	$(2l + 2j_l)$ / $(l + E_T^{miss} + 2j_l)$	$(2l + 2b)$ / $(l + E_T^{miss} + 2b)$	$(2l + 4j_l + 2t)$ / $(l + E_T^{miss} + 4j_l + t + b)$	$(2l + 2j_l + 2b + 2t)$ / $(l + E_T^{miss} + 2j_l + 3b + t)$
$\tilde{u}$	$(2l + 6j_l)$ / $(l + E_T^{miss} + 6j_l)$	$(2l + 4j_l + 2b)$ / $(l + E_T^{miss} + 4j_l + 2b)$	$(2l + 4j_l + 2t)$ / $(l + E_T^{miss} + 4j_l + t + b)$	$(2l + 2j_l + 2b + 2t)$ / $(l + E_T^{miss} + 2j_l + 3b + t)$
$\tilde{d}$	$(2l + 2j_l)$ / $(l + E_T^{miss} + 2j_l)$	$(2l + 4j_l + 2b)$ / $(l + E_T^{miss} + 4j_l + 2b)$	$(2l + 2t)$ / $(l + E_T^{miss} + t + b)$	$(2l + 2j_l + 2b + 2t)$ / $(l + E_T^{miss} + 2j_l + 3b + t)$
$\tilde{t}_L\,(\tilde{b}_L)$	$(2l + 2j_3 + 4j_l)$ / $(l + E_T^{miss} + 2j_3 + 4j_l)$	$(2l + 2j_3 + 2b + 2j_l)$ / $(l + E_T^{miss} + 2j_3 + 2b + 2j_l)$	$(2l + 2j_l)$	$(2l + 2b)$
$\tilde{t}_R$	$(2l + 4j_l + 2j_3)$ / $(l + E_T^{miss} + 4j_l + 2j_3)$	$(2l + 2j_l + 2j_3 + 2b)$ / $(l + E_T^{miss} + 2j_l + 2j_3 + 2b)$	$(2l + 2j_l + 2j_3 + 2t)$ / $(l + E_T^{miss} + 2j_l + 2j_3 t + b)$	$(2l + 2j_3 + 2b + 2t)$ / $(l + E_T^{miss} + 2j_3 + 3b + t)$
$\tilde{b}_R$	$(2l + 2b + 4j_l)$ / $(l + E_T^{miss} + 2b + 4j_l)$	$(2l + 2j_l)$ / $(l + E_T^{miss} + 2j_l)$	$(2l + 2j_l + 2t + 2b)$ / $(l + E_T^{miss} + 2j_l + t + 3b)$	$(2l + 2t)$ / $(l + E_T^{miss} + b)$
$\tilde{B}/\tilde{W}/\tilde{H}$	$(2l + 4j_l)$ / $(l + E_T^{miss} + 4j_l)$	$(2l + 2j_l + 2b)$ / $(l + E_T^{miss} + 2j_l + 2b)$	$(2l + 2t + 2j_l)$ / $(1l + E_T^{miss} + t + b + 2j_l)$ / $(\mathbf{E_T^{miss} + 2b + 2j_l})$	$(2l + 2t + 2b)$ / $(1l + E_T^{miss} + t + 3b)$ / $(\mathbf{E_T^{miss} + 4b})$

LSP	$\mathrm{L_3QD}$ (V)	$\mathrm{L_3QD_3}$ (VI)	$\mathrm{L_3Q_3D}$ (VII)	$\mathrm{L_3Q_3D_3}$ $(VIII)$
$\tilde{l}\,(\tilde{\nu})$	$(2l + 2\tau + 4j_l)$ / $(1l + 2\tau + 4j_l + E_T^{miss})$	$(2l + 2\tau + 2j_l + 2b)$ / $(1l + 2\tau + 2j_l + 2b + E_T^{miss})$	$(2l + 2\tau + 2t + 2j_l)$ / $(1l + 2\tau + 2t + 2j_l + E_T^{miss})$ / $(2l + 2b + 2j_l + E_T^{miss})$ / $(l + 2b + 2j_l + E_T^{miss})$	$(2l + 2\tau + 2t + 2b)$ / $(1l + 2\tau + 2t + 2b + E_T^{miss})$ / $(2l + 4b + E_T^{miss})$ / $(l + 4b + E_T^{miss})$
$\tilde{e}$	$(2l + 2\tau + 4j_l)$ / $(2l + 1\tau + 4j_l + E_T^{miss})$	$(2l + 2\tau + 2j_l + 2b)$ / $(2l + 1\tau + 2j_l + 2b + E_T^{miss})$	$(2l + 2\tau + 2j_l + 2t)$ / $(2l + 1\tau + 2j_l + t + b + E_T^{miss})$ / $(2l + 2j_l + 2b + E_T^{miss})$	$(2l + 2\tau + 2t + 2b)$ / $(2l + 1\tau + t + 3b + E_T^{miss})$ / $(2l + 4b + E_T^{miss})$
$\tilde{\tau}\,(\tilde{\nu}_\tau)/\tilde{\tau}_R$	$\mathbf{4j_l}$	$\mathbf{2b + 2j_l}$	$\mathbf{(2j_3 + 2j_l)}$	$\mathbf{(2b + 2j_3)}$
$\tilde{\tau}_R$	$(4\tau + 4j_l)$ / $(3\tau + 4j_l + E_T^{miss})$	$(4\tau + 2j_l + 2b)$ / $(3\tau + 2j_l + 2b + E_T^{miss})$	$(4\tau + 2j_l + 2t)$ / $(3\tau + 2j_l + t + b + E_T^{miss})$ / $(2\tau + 2j_l + 2b + E_T^{miss})$	$(4\tau + 2t + 2b)$ / $(3\tau + t + 3b + E_T^{miss})$ / $(2\tau + 4b + E_T^{miss})$
$\tilde{g}$	$(2l + 4j_l)$ / $(l + E_T^{miss} + 4j_l)$	$(2l + 2j_l + 2b)$ / $(l + E_T^{miss} + 2j_l + 2b)$	$(2l + 2j_l + 2t)$ / $(l + E_T^{miss} + 2j_l + t + b)$	$(2l + 2b + 2t)$ / $(l + E_T^{miss} + 3b + t)$
$\tilde{q}$	$(2\tau + 2j_l)$ / $(\tau + E_T^{miss} + 2j_l)$	$(2\tau + 2b)$ / $(\tau + E_T^{miss} + 2b)$	$(2\tau + 4j_l + 2t)$ / $(\tau + E_T^{miss} + 4j_l + t + b)$	$(2\tau + 2j_l + 2b + 2t)$ / $(\tau + E_T^{miss} + 2j_l + 3b + t)$
$\tilde{u}$	$(2\tau + 6j_l)$ / $(\tau + E_T^{miss} + 6j_l)$	$(2\tau + 4j_l + 2b)$ / $(\tau + E_T^{miss} + 4j_l + 2b)$	$(2\tau + 4j_l + 2t)$ / $(\tau + E_T^{miss} + 4j_l + t + b)$	$(2\tau + 2j_l + 2b + 2t)$ / $(\tau + E_T^{miss} + 2j_l + 3b + t)$
$\tilde{d}$	$(2\tau + 2j_l)$ / $(\tau + E_T^{miss} + 2j_l)$	$(2\tau + 4j_l + 2b)$ / $(\tau + E_T^{miss} + 4j_l + 2b)$	$(2\tau + 2t)$ / $(\tau + E_T^{miss} + t + b)$	$(2\tau + 2j_l + 2b + 2t)$ / $(\tau + E_T^{miss} + 2j_l + 3b + t)$
$\tilde{t}_L\,(\tilde{b}_L)$	$(2\tau + 2j_3 + 4j_l)$ / $(\tau + E_T^{miss} + 2j_3 + 4j_l)$	$(2\tau + 2j_3 + 2b + 2j_l)$ / $(\tau + E_T^{miss} + 2j_3 + 2b + 2j_l)$	$(2\tau + 2j_l)$	$(2\tau + 2b)$
$\tilde{t}_R$	$(2\tau + 4j_l + 2j_3)$ / $(\tau + E_T^{miss} + 4j_l + 2j_3)$	$(2\tau + 2j_l + 2j_3 + 2b)$ / $(\tau + E_T^{miss} + 2j_l + 2j_3 + 2b)$	$(2\tau + 2j_l + 2j_3 + 2t)$ / $(\tau + E_T^{miss} + 2j_l + 2j_3 t + b)$	$(2\tau + 2j_3 + 2b + 2t)$ / $(\tau + E_T^{miss} + 2j_3 + 3b + t)$
$\tilde{b}_R$	$(2\tau + 2b + 4j_l)$ / $(\tau + E_T^{miss} + 2b + 4j_l)$	$(2\tau + 2j_l)$ / $(\tau + E_T^{miss} + 2j_l)$	$(2\tau + 2j_l + 2t + 2b)$ / $(\tau + E_T^{miss} + 2j_l + t + 3b)$	$(2\tau + 2t)$ / $(\tau + E_T^{miss} + b)$
$\tilde{B}/\tilde{W}/\tilde{H}$	$(2\tau + 4j_l)$ / $(\tau + E_T^{miss} + 4j_l)$	$(2\tau + 2j_l + 2b)$ / $(\tau + E_T^{miss} + 2j_l + 2b)$	$(2\tau + 2t + 2j_l)$ / $(1\tau + E_T^{miss} + t + b + 2j_l)$ / $(\mathbf{E_T^{miss} + 2b + 2j_l})$	$(2\tau + 2t + 2b)$ / $(1\tau + E_T^{miss} + t + 3b)$ / $(\mathbf{E_T^{miss} + 4b})$

- l: e/μ
- L: $e/\mu/\tau$
- j_l: light jet
- b: bottom jet
- t: top jet
- j_3: b/t
- J: j_l/j_3

1. Four leptons: $4L + 4J$
2. Three leptons: $3L + E_T^{miss} + 4J$
3. Two leptons: $2L + \geq 2J$
4. One lepton: $1L + E_T^{miss} + \geq 2J$
5. Zero lepton: $4J\,(+E_T^{miss})$

Where to?

Also classified production channels; we have a dictionary

- $\tilde{q}$ LSP
  - $\tilde{g}\tilde{g}$ $+2j_l$
  - $\tilde{g}\tilde{q}$ $+1j_l/3j_l$
  - $\tilde{q}\tilde{q}$ $+-/4j_l$
- $\tilde{W}$ LSP
  - $\tilde{g}\tilde{g}$ $+4j_l/4j_t/4j_b$
  - $\tilde{g}\tilde{q}$ $+1j_l+2j_l/2j_t/2j_b$
  - $\tilde{g}\tilde{u}/\tilde{g}\tilde{d}$ $+1j_l+4j_l/4j_t/4j_b$
  - $\tilde{q}\tilde{q}$ $+2j_l$
  - $\tilde{u}\tilde{u}/\tilde{d}\tilde{d}$ $+2j_l+4j_l/4j_t/4j_b$
  - $\tilde{t}\tilde{t}$ $+2j_t$
  - $\tilde{b}\tilde{b}$ $+2j_b$
  - $\tilde{t}_R\tilde{t}_R$ $+?$
  - $\tilde{b}_R\tilde{b}_R$ $+?$
  - $\tilde{W}\tilde{W}$ $+-$
- $\tilde{l}/\tilde{\nu}$ LSP
  - $\tilde{g}\tilde{g}$ $+2l+4j_l/4j_t/4j_b$
  - $\tilde{g}\tilde{q}/\tilde{g}\tilde{u}/\tilde{g}\tilde{d}$ $+2l+1j_l+2j_l/2j_t/2j_b$
  - $\tilde{q}\tilde{q}/\tilde{u}\tilde{u}/\tilde{d}\tilde{d}$ $+2l+2j_l$
  - $\tilde{t}\tilde{t}/\tilde{t}_R\tilde{t}_R$ $+2l+2j_t$
  - $\tilde{b}\tilde{b}/\tilde{b}_R\tilde{b}_R$ $+2l+2j_b$
  - $\tilde{W}\tilde{W}$ $+2l$
  - $\tilde{H}\tilde{H}$ $+?$
  - $\tilde{l}\tilde{\nu}/\tilde{l}\tilde{l}/\tilde{\nu}\tilde{\nu}$ $+-$

Outlook

Next Steps?

- Neat classification. Reduces most general RPV to few signatures. But is it useful?
- Use it to identify gaps in current literature -> extensive survey
- Use it to identify new benchmark searches
- KY Sheng working on code that will quantify these results
- Eventually make similar dictionary for large RPV coupling case: Direct decays, Single production

Thanks for your time!