Searches for Signatures of R-Parity Violating (RPV) Supersymmetry Models in ATLAS

SUSY 2014, Manchester, UK

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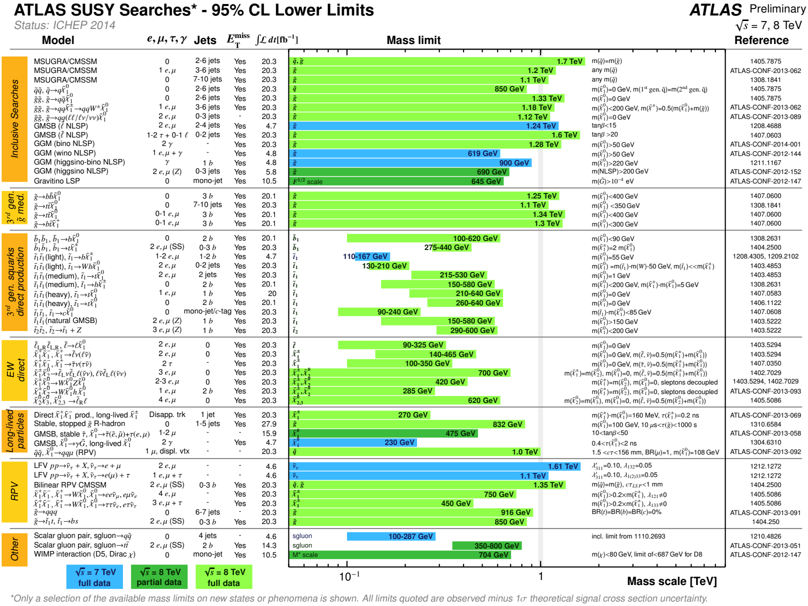
THE UNIVERSITY OF CHICAGO

Monday, July 21st, 2014



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: ICHEP 2014

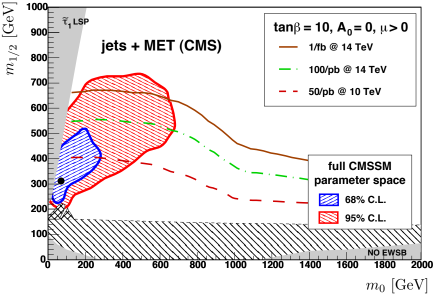
ATLAS Preliminary
$\sqrt{s}$ = 7, 8 TeV

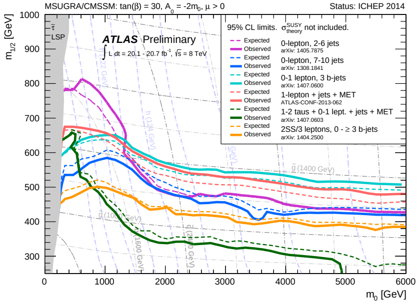
	Model	e, μ, τ, γ	Jets	$E_{\mathrm{T}}^{\mathrm{miss}}$	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1405.7875
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any m($\tilde{q}$)	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any m($\tilde{q}$)	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 850 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{g}\tilde{g}$, $\tilde{g}\rightarrow q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.33 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1405.7875
	$\tilde{g}\tilde{g}$, $\tilde{g}\rightarrow qq\tilde{\chi}_1^{\pm}\rightarrow qqW^{\pm}\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}^{\pm}$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\rightarrow qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.6 TeV	tanβ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	m($\tilde{\chi}_1^0$)>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	m(NLSP)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	m($\tilde{G}$)>10^{-4} eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\rightarrow b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.25 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\rightarrow b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\rightarrow t\tilde{\chi}_1^{\pm}$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$ 275-440 GeV	m($\tilde{\chi}_1^{\pm}$)=2 m($\tilde{\chi}_1^0$)	1404.2500
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\rightarrow b\tilde{\chi}_1^{\pm}$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	m($\tilde{\chi}_1^0$)=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\rightarrow Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-210 GeV	m($\tilde{\chi}_1^0$) =m($\tilde{t}_1$)-m(W)-50 GeV, m($\tilde{t}_1$)<<m($\tilde{\chi}_1^{\pm}$)	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\rightarrow t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$ 215-530 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\rightarrow b\tilde{\chi}_1^{\pm}$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\rightarrow t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20	$\tilde{t}_1$ 210-640 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1407.0583
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\rightarrow t\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{t}_1$ 260-640 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1406.1122
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\rightarrow c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-240 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\rightarrow\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{\mathrm{L,R}}\tilde{\ell}_{\mathrm{L,R}}$, $\tilde{\ell}\rightarrow\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\rightarrow\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 140-465 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\rightarrow\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 100-350 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1407.0350
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow\tilde{\ell}_{\mathrm{L}}\nu\tilde{\ell}_{\mathrm{L}}\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_{\mathrm{L}}\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 700 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 420 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 285 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	ATLAS-CONF-2013-093
	$\tilde{\chi}_2^0\tilde{\chi}_3^0$, $\tilde{\chi}_{2,3}^0\rightarrow\tilde{\ell}_{\mathrm{R}}\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 620 GeV	m($\tilde{\chi}_2^0$)=m($\tilde{\chi}_3^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_2^0$)+m($\tilde{\chi}_1^0$))	1405.5086
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 270 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)=160 MeV, τ($\tilde{\chi}_1^{\pm}$)=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	1310.6584
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\rightarrow\tilde{\tau}(\tilde{e}, \tilde{\mu})+\tau(e, \mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$ 475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\rightarrow\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	0.4<τ($\tilde{\chi}_1^0$)<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\rightarrow qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, m($\tilde{\chi}_1^0$)=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\rightarrow\tilde{\nu}_{\tau} + X, \tilde{\nu}_{\tau}\rightarrow e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_{\tau}$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\rightarrow\tilde{\nu}_{\tau} + X, \tilde{\nu}_{\tau}\rightarrow e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_{\tau}$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.35 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow ee\tilde{\nu}_{\mu}, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 750 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^{\pm}$), $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_{\tau}$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 450 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^{\pm}$), $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\rightarrow qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\rightarrow\tilde{t}_1 t, \tilde{t}_1\rightarrow bs$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 850 GeV		1404.250
Other	Scalar gluon pair, sgluon→$q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon→$t\bar{t}$	2 e, μ (SS)	2 b	Yes	14.3	sgluon 350-800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	m(χ)<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

$\sqrt{s}$ = 7 TeV full data	$\sqrt{s}$ = 8 TeV partial data	$\sqrt{s}$ = 8 TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

New Perspectives: SUSY is not just around the corner


Buchmuller (2008) [1]


ATLAS, jets+MET (2012, $\sqrt{s} = 8$ TeV) [2]

> *"No reasonable person could view these figures together without concluding that we need to change our perspective. But, what new perspective is called for?"*

– M. E. Peskin, Lepton-Photon 2011 [3]

Hiding Supersymmetry through R-Parity Violation

The RPV superpotential

Direct decay of sparticles to SM particles can occur in *R*-parity violating (RPV) SUSY via three general terms:

- Lepton number violating (LNV) term: *LLE* via λ_{ijk} (multileptons)

$$W_{\not{R}_p} = \frac{1}{2}\lambda_{ijk}L_iL_j\bar{E}_k + \lambda'_{ijk}L_iQ_j\bar{D}_k + \frac{1}{2}\lambda''_{ijk}\bar{U}_i\bar{D}_j\bar{D}_k + \kappa_iL_iH_2$$

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- LNV term: *LQD* via λ'_{ijk} (leptons+jets)

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- Baryon number violating (BNV) term: *UDD* via λ''_{ijk} (multijets)

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- Bilinear lepton-gaugino mixing term: LH via κ

Hiding Supersymmetry through R-Parity Violation

The RPV superpotential

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- LNV term: *LQD* via λ'_{ijk} (leptons+jets)

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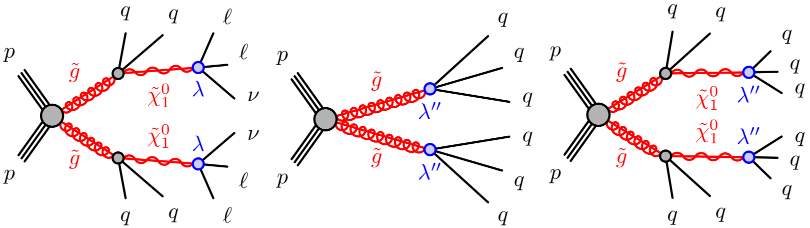
- Baryon number violating (BNV) term: *UDD* via λ''_{ijk} (multijets)
- Bilinear lepton-gaugino mixing term: LH via κ

The *UDD* term (λ''_{ijk}) is generally least constrained via collider experiments, in part because **the all-hadronic decays are hard to constrain**.

Hunting for RPV SUSY: the signals that we're after



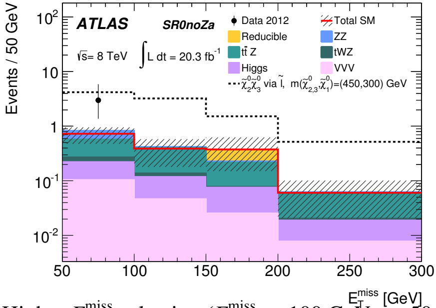
- **Multilepton production from neutralino LLE (λ_{ijk}) LNV decays**
  - Prompt production of many leptons and large $E_{\mathrm{T}}^{\mathrm{miss}}$ and M_{eff}
- **Multijet production from gluino UDD (λ''_{ijk}) BNV decays**
  - Massive multijet final states, very tough background estimation

Multilepton search

4-lepton RPV+RPC SUSY search (arXiv:1405.5086)

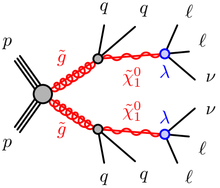
Concept: Look for events with 4 leptons (at least 2 e or μ) and significant $E_{\mathrm{T}}^{\mathrm{miss}}$ from ν's. Separately consider $\geq 0, 1, 2\tau$ events.

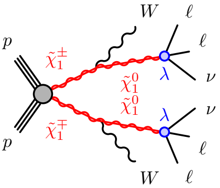
- **Veto low mass** ($m_{\ell\ell} < 12$ GeV) or $m_{\ell\ell} \approx m_Z$ events for same-flavor, opposite sign (SFOS) lepton pairs
- Estimate **reducible** backgrounds ($\geq$1 fake) from data
- Estimate **irreducible** (mostly SM) backgrounds from Monte Carlo (MC)



Higher $E_{\mathrm{T}}^{\mathrm{miss}}$ selection ($E_{\mathrm{T}}^{\mathrm{miss}} > 100$ GeV vs. 50 GeV) for events required to have 1 τ.

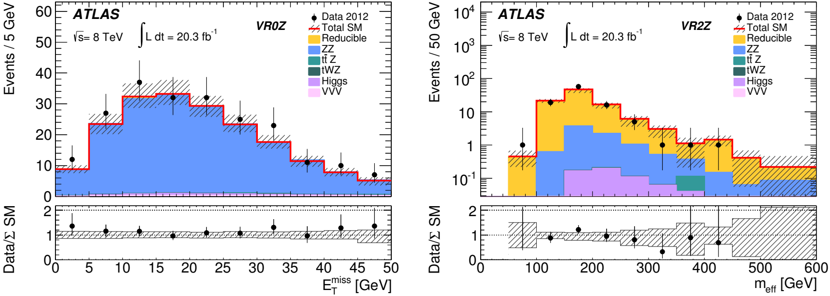
Signal regions for RPV signals add $M_{\mathrm{eff}} > 400, 600$ GeV selection





Background estimation and validation

4-lepton RPV+RPC SUSY search (arXiv:1405.5086)

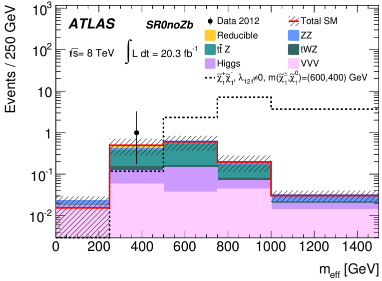


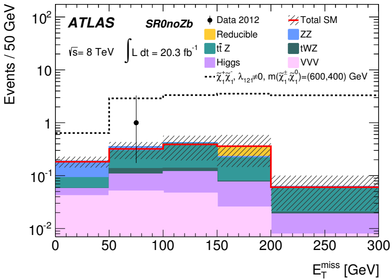
	N(ℓ)	N(τ)	Z-requirement	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	
VR0Z	≥4	≥0	SFOS	<50	–
VR1Z	=3	≥1	SFOS	<50	–
VR2Z	=2	≥2	SFOS	<50	–

- **(Left):** Validation of the MC estimates for the irreducible backgrounds
- **(Right):** Validation of the data-driven estimates for the reducible backgrounds

Signal region observations

4-lepton RPV+RPC SUSY search (arXiv:1405.5086)





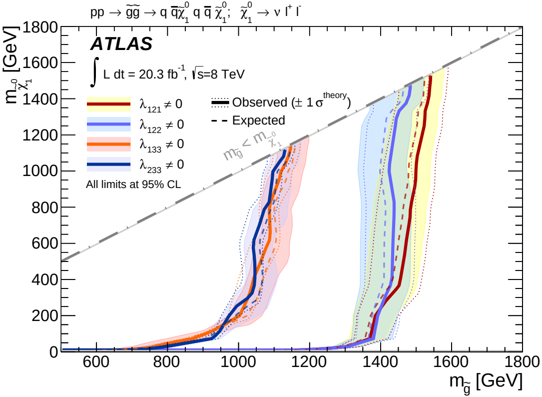
	N(ℓ)	N(τ)	Z-veto	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]		m_{eff} [GeV]
SR0noZa	≥ 4	≥ 0	SFOS, SFOS+ℓ, SFOS+SFOS	>50		–
SR1noZa	$=3$	≥ 1	SFOS, SFOS+ℓ	>50		–
SR2noZa	$=2$	≥ 2	SFOS	>75		–
SR0noZb	≥ 4	≥ 0	SFOS, SFOS+ℓ, SFOS+SFOS	>75	or	>600
SR1noZb	$=3$	≥ 1	SFOS, SFOS+ℓ	>100	or	>400
SR2noZb	$=2$	≥ 2	SFOS	>100	or	>600

Benchmark model limits: strong production

4-lepton RPV+RPC SUSY search (arXiv:1405.5086)

Significant sensitivity due to unique final state and high production cross section.

- Multiple couplings explored independently
- Similar sensitivity for different light flavor couplings, or heavy flavor combinations
- Heavy flavor (τ) cross section limits are significantly weaker



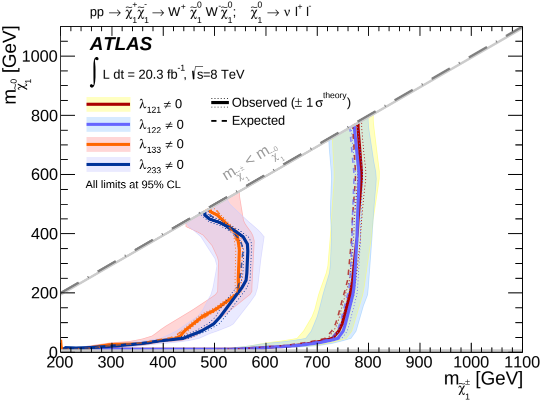
Reconstruction efficiency drops significantly when the $\tilde{\chi}_1^0$ is significantly less massive than the $\tilde{g}$ and becomes boosted.

Benchmark model limits: weak production

4-lepton RPV+RPC SUSY search (arXiv:1405.5086)

Sensitivity drops for lower cross-section weak production scenarios.

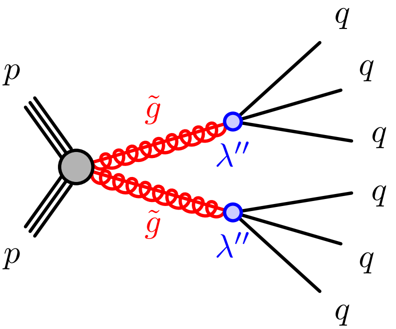
- If $m_{\tilde{\chi}_1^0} > 0.2 m_{\tilde{\chi}_1^\pm}$ then a lower limit on wino-like charginos of 450 GeV is observed
- Similar sensitivity for different light flavor couplings, or heavy flavor combinations
- Heavy flavor (τ) cross section limits are significantly weaker

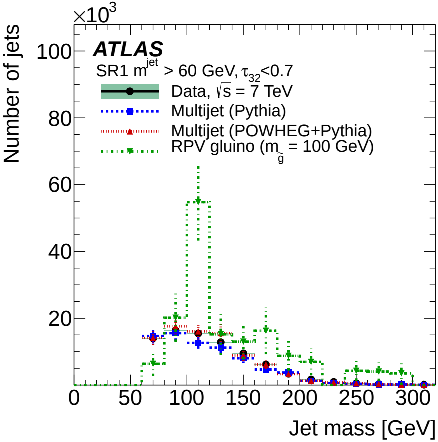


A limit of 400 GeV can be placed on sneutrino masses for RPV models with electron and muon decays of the LSP.

Looking for SUSY in multijet events

RPV gluino 2×3 jet search (arXiv:1210.4813)





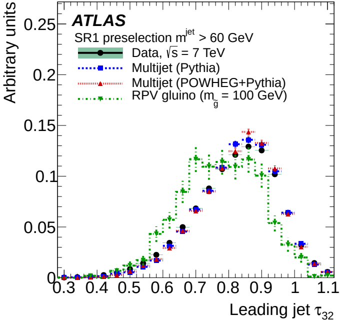
Singe jet mass from merged gluino ($\tilde{g}$) quark decay products

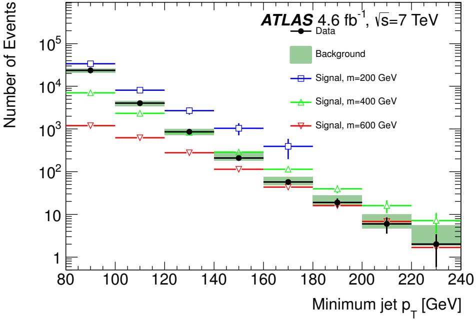
Two approaches to background discrimination:

- Resolved jet counting method
- Merged jet resonance method

Background discrimination

RPV gluino 2 × 3 jet search (arXiv:1210.4813)

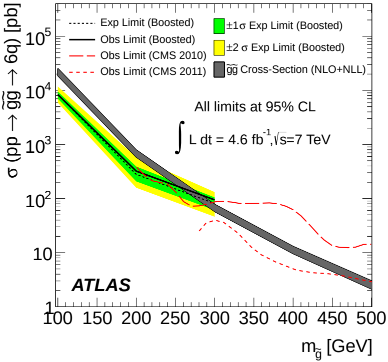




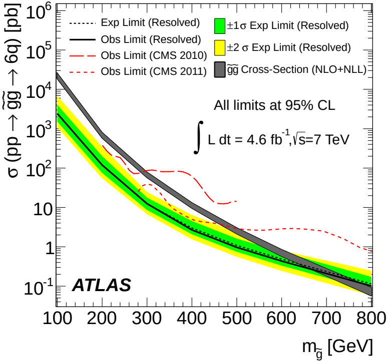
- **Merged – Left:** In addition to jet mass (previous slide) use shape observable called "τ_{32}" (estimates subjets in jet) to select signal
- **Resolved – Right:** Focus only on jet multiplicity (no 3-body mass) and estimate by projecting from lower jet multiplicity bins

RPV gluino limits: boosted + jet counting

Boosted RPV gluino search (arXiv:1210.4813)



Boosted limits (jet mass and substructre)



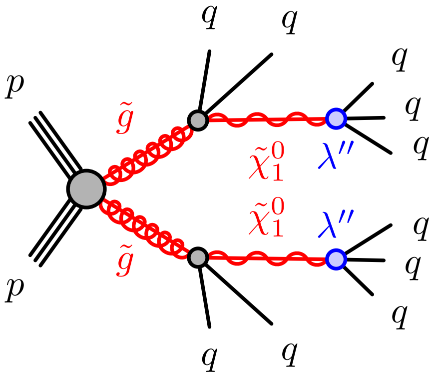
Resolved limits (jet counting)

- Both analyses exclude top-mass region (non-trivial!)
- Resolved analysis uses very tight selections and relies on MC to model jet multiplicity → excludes up to $m_{\tilde{g}} > 666$ GeV

Extending the search at 8 TeV

ATLAS-CONF-2013-091

Gluino ($\tilde{g}$) pair production, decaying with $\tilde{g} \to \tilde{q}q$, $\tilde{q} \to \tilde{\chi}_1^0 q$, $\tilde{\chi}_1^0 \to 3q$

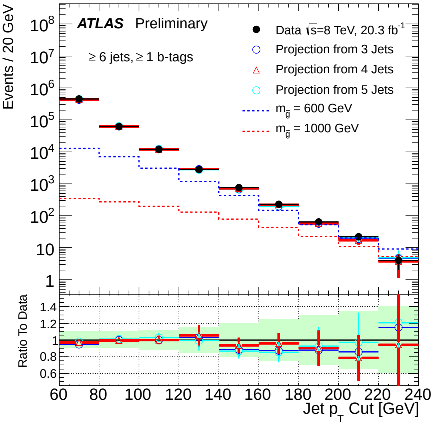


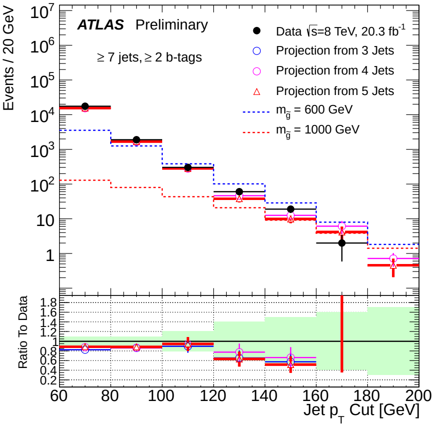
A natural, UDD RPV model: final state characterized by many partons

- Between **10** (light quarks) and **22** (tops) partons in final state
- Very challenging environment!

Updated multijet search for 8 TeV

ATLAS-CONF-2013-091

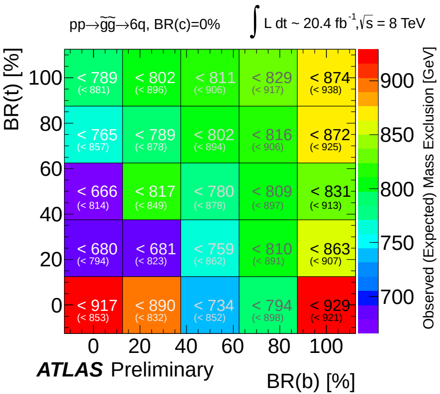


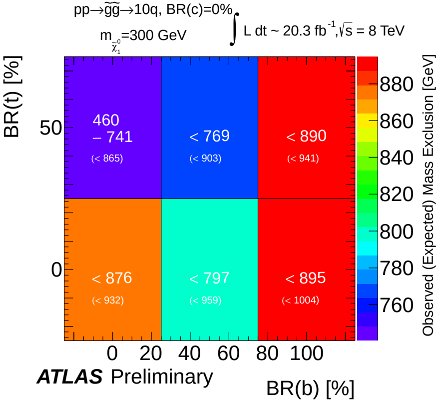


- **New for 8 TeV:** use *b*-tagging information to estimate branching ratios of various RPV decays to different flavors

Multijet search results for 8 TeV

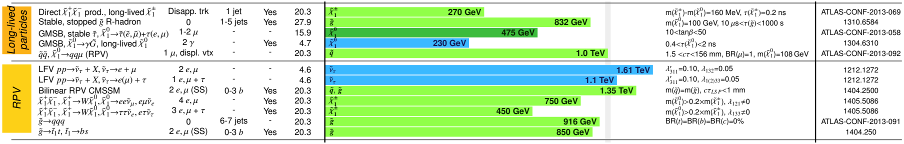
ATLAS-CONF-2013-091





- Set limits in the branching ratio plane: BR(t) vs. BR(b)
- Constrain the gluino masses for given neutralino masses and branching ratio assumptions

ATLAS RPV Search Summary



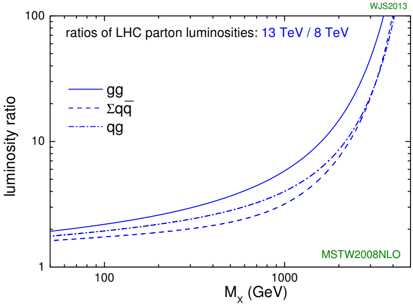
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$	832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\rightarrow\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\rightarrow\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\rightarrow qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, m($\tilde{\chi}_1^0$)=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\rightarrow\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\rightarrow e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\rightarrow\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\rightarrow e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$	1.35 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\rightarrow ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.3	$\tilde{\chi}_1^\pm$	750 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^\pm$), $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\rightarrow\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.3	$\tilde{\chi}_1^\pm$	450 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^\pm$), $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\rightarrow qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\rightarrow\tilde{t}_1 t$, $\tilde{t}_1\rightarrow bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$	850 GeV		1404.250

- Many other searches done and underway!
- Keep an eye out for new results over the next few months
- Work proceeding towards Run II

Early Run II Expectations

Early 2015 LHC Program:

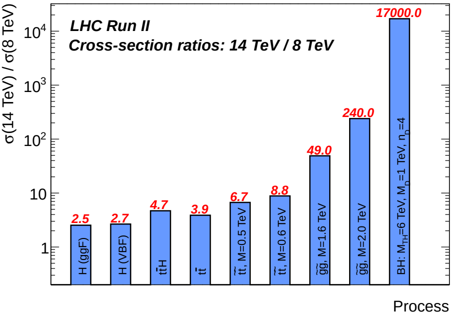
- **May:** Stable beams operation with 50ns bunch spacing after intensity ramp-up
- **June:** Stable beams operation with 25ns bunch spacing after intensity ramp-up



Strong production processes see biggest increase! →

Outlook for 2015:

- Huge increase in discovery potential
- Suggests a strong focus on targeted searches very early
- Both short-term and longer-term efforts will depend on detector performance
- With 3 fb^{-1} many searches reach or surpass current sensitivity



A rich program in RPV SUSY searches

- **A well motivated alternative avenue compared to the standard jet+$E_{\mathrm{T}}^{\mathrm{miss}}$searches**
  - Performance of novel techniques demonstrated at $\sqrt{s} = 7$ TeV and ongoing at $\sqrt{s} = 8$ TeV
  - Challenging background estimations but very sensitive searches
  - Limits are approaching the 1 TeVrange for RPV hadronic final states
- **Extending and enhancing the interpretations of results**
  - Increasing the phase space of interpretations by considering mixed branching ratios and additional couplings
- **Focus shifting to Run II searches**
  - Center-of-mass energy increase dramatically enhances strong production processes and the potential for discovery of new resonances
  - Expect RPV searches to play significant role in initial physics program of Run II

Additional Material

Control region definitions

Boosted RPV gluino search (arXiv:1210.4813)

Region	Jet (J_1) selections	Jet (J_2) selections	Description
CR-A	$m^{\text{jet}} < M_{\text{threshold}}$	$m^{\text{jet}} < M_{\text{threshold}}$	Low-mass jets, to validate τ_{32} shape
CR-B	$m^{\text{jet}} > M_{\text{threshold}}$ $\tau_{32} < 0.7$	$m^{\text{jet}} < M_{\text{threshold}}$	Signal-like leading jet, to validate m^{jet}
CR-C	$m^{\text{jet}} < M_{\text{threshold}}$	$m^{\text{jet}} > M_{\text{threshold}}$ $\tau_{32} < 0.7$	Signal-like subleading jet, to validate m^{jet}

Accounting for correlations between control regions:

$$N_{SR} = N_{\text{CR-C}} \times \left(\frac{N_{\text{CR-B}}}{N_{\text{CR-A}}}\right) \times \alpha_{MC} \tag{1}$$

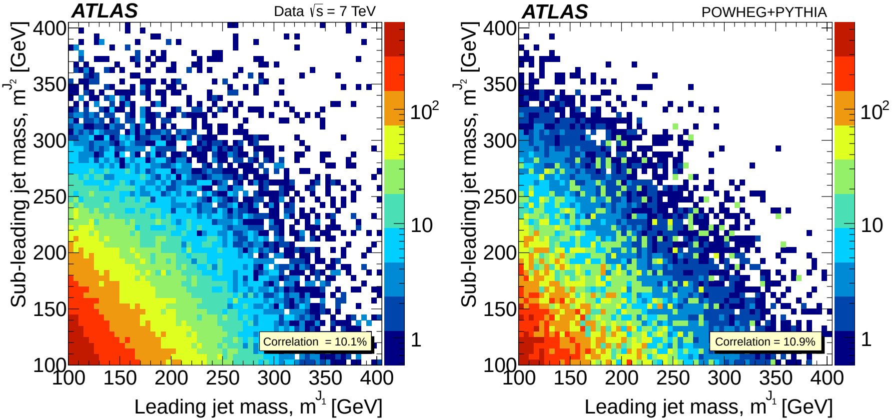
$$\alpha = \left(\frac{N_{SR} \,/\, N_{\text{CR-C}}}{N_{\text{CR-B}} \,/\, N_{\text{CR-A}}}\right)\Bigg|_{\text{POWHEG MC}} \tag{2}$$

- **Syst:** jet kinematic and tagging ssytematics in each signal and control region separately
- **MC Syst:** difference between `POWHEG` and `PYTHIA` is taken as an additional systematic uncertainty

Trimmed jet mass correlations ($m^{\mathrm{jet}} > 100$ GeV)

Boosted RPV gluino search (arXiv:1210.4813)

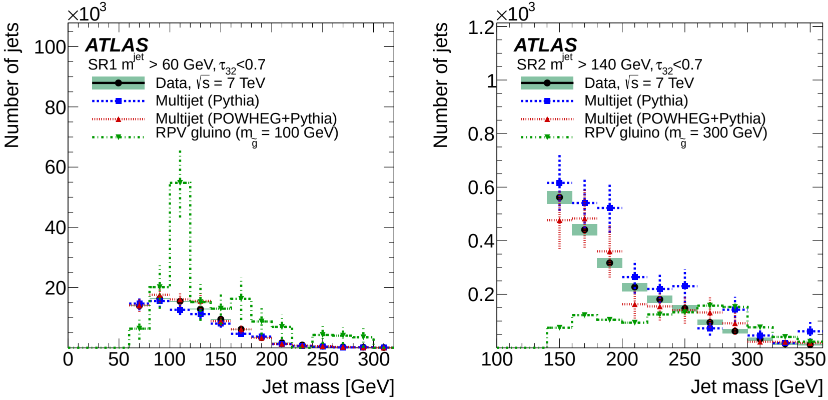
- Correlations between leading and subleading (in $p_{\mathrm{T}}^{\mathrm{jet}}$) jet masses



- **Data:** 10.1%, **`POWHEG`:** 10.9% (trimmed)
- Excellent agreement between data and `POWHEG` at high leading-jet mass

Boosted gluino mass distributions

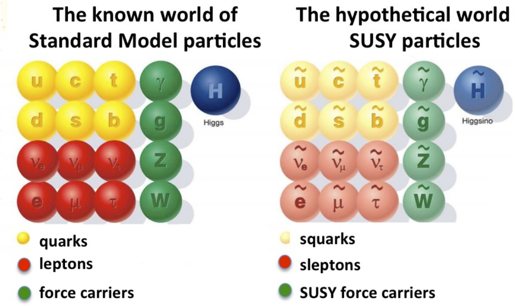
Boosted RPV gluino search (arXiv:1210.4813)



- Distinct signature of RPV $\tilde{g}$
- Incomplete "merging" of $\tilde{g}$ decay products for $m_{\tilde{g}}$ =300 GeV, but still good discrimination (peak at $m^{\text{jet}} \approx 275$ GeV)

*Attractive "Answer" to **some** of the open questions: SUSY*

Supersymmetry (SUSY) provides not only an attractive, and seemingly *natural* symmetry, by **relating fermions to bosons**, but also hopes to solve a few of the problems mentioned above.



- A potential Dark Matter candidate
  - If *R*-parity is conserved
- The potential for unifying the Strong, electromagnetic, and weak forces
- Stabilizing the Higgs mass

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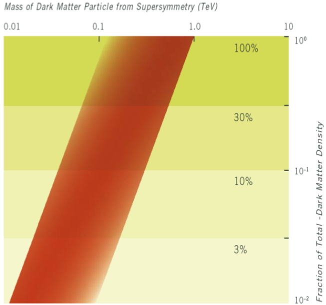

HEPAP 2006 LHC/ILC Subpanel

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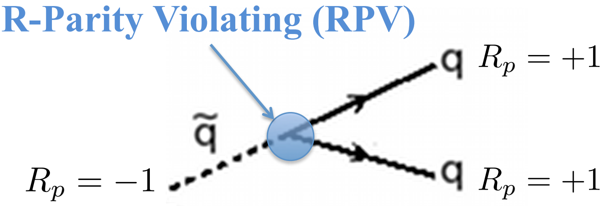

$$R - \text{parity}: \quad R_p = (-1)^R = (-1)^{2S}(-1)^{3B+L}$$

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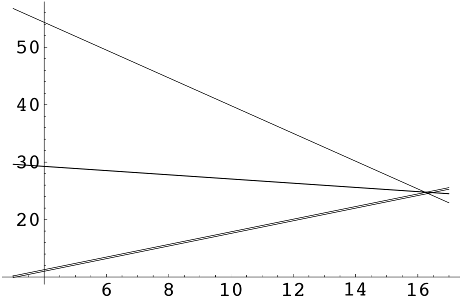

(Arkani-Hamed and Dimopoulos, 2004 [4])

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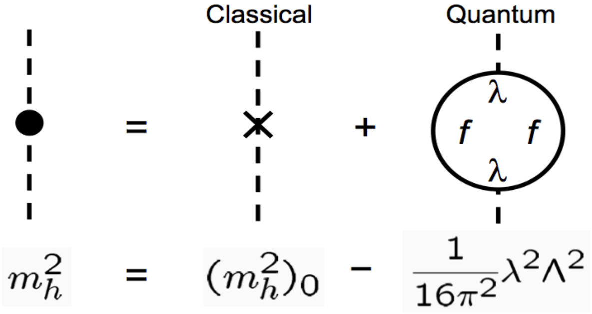

$$m_h^2 = (m_h^2)_0 - \frac{1}{16\pi^2}\lambda^2\Lambda^2$$

(Hewitt, SSI 2012)

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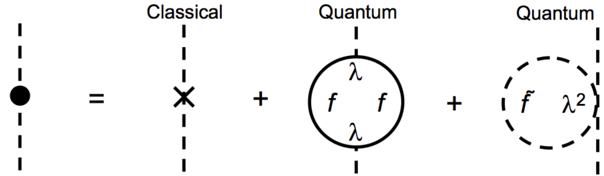

$$m_h^2 = (m_h^2)_0 \underbrace{- \frac{1}{16\pi^2}\lambda^2\Lambda^2 + \frac{1}{16\pi^2}\lambda^2\Lambda^2}_{+\frac{1}{16\pi^2}\lambda^2(m_{\tilde f}^2 - m_f^2)\ln(\Lambda/m_h)}$$

(Hewitt, SSI 2012)

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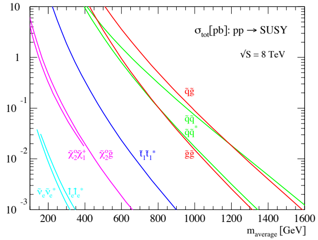
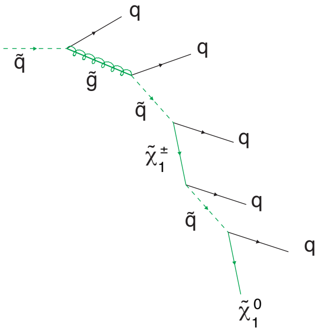
The Ingredients of a SUSY Search

A decades-old approach using jets+E_T^{miss}

- **Squarks ($\tilde{q}$) and gluinos ($\tilde{g}$) are strongly produced in pairs**
  - Dominant production mode
  - Preference for $\tilde{q}$ vs. $\tilde{g}$ depends on $m_{\tilde{q}}$ vs. $m_{\tilde{g}}$
- **Decay chain leads to many jets and E_T^{miss}**
  - **Frequent assumption:** Neutralino ($\tilde{\chi}_1^0$) is the lightest super symmetric particle and escapes detection, creating E_T^{miss}
  - Leptons also possible
- **Search strategies so far have relied on number of jets and E_T^{miss}**
  - $H_T = \sum_{\text{jets}} p_T^{\text{jet}} + \left(\sum_{\text{leptons}} p_T^{\text{leptons}} + \ldots \right)$
  - $M_{\text{eff}} = E_T^{\text{miss}} + H_T$





Long SUSY cascade decay

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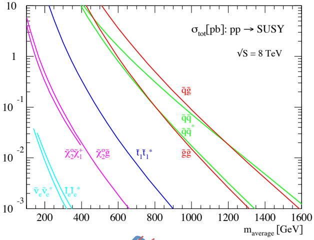

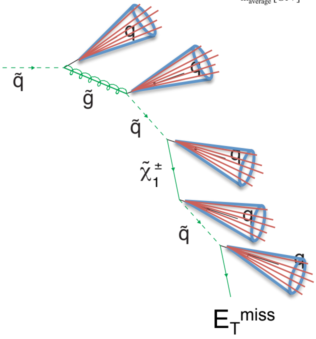

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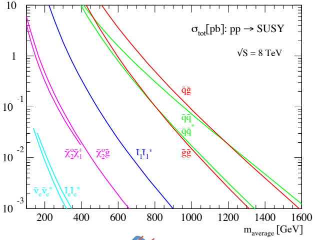
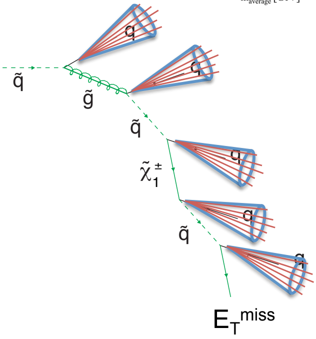
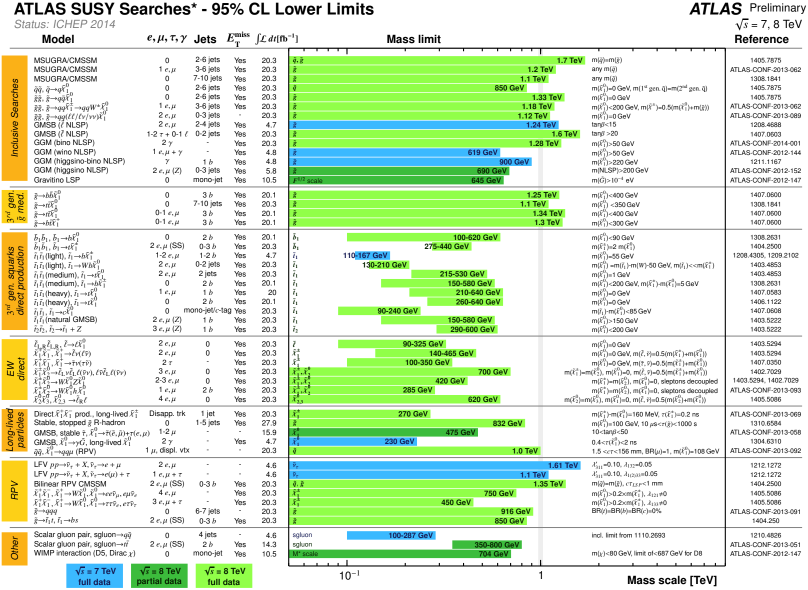




Long SUSY cascade decay



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: ICHEP 2014

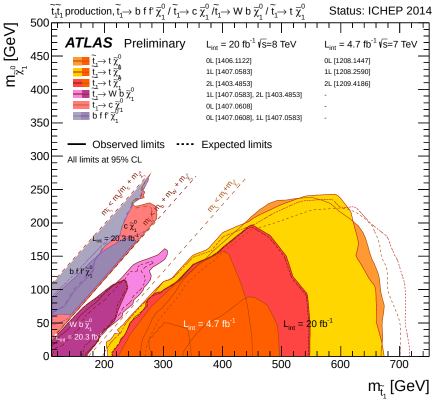
ATLAS Preliminary

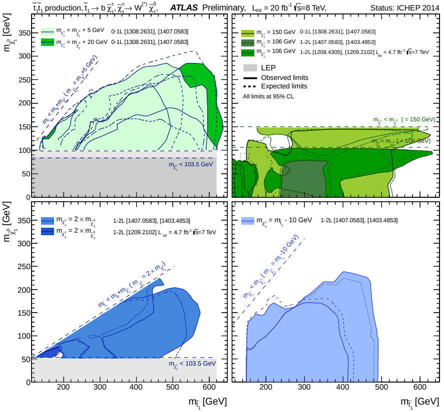
$\sqrt{s}$ = 7, 8 TeV

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q},\tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	1405.7875
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 850 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.33 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	1405.7875
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}^{\pm}_1\to qqW^{\pm}\tilde{\chi}^0_1$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}^0_1)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}^0_1$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.6 TeV	tanβ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	$m(\tilde{\chi}^0_1)$>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}^0_1)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}^0_1)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	m(NLSP)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{G})>10^{-4}$ eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}^0_1$	0	3 b	Yes	20.1	$\tilde{g}$ 1.25 TeV	$m(\tilde{\chi}^0_1)$<400 GeV	1407.0600
	$\tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}^0_1)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}^0_1)$<400 GeV	1407.0600
	$\tilde{g}\to b\bar{t}\tilde{\chi}^+_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}^0_1)$<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}^0_1$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}^0_1)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}^{\pm}_1$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$ 275-440 GeV	$m(\tilde{\chi}^{\pm}_1)$=2 $m(\tilde{\chi}^0_1)$	1404.2500
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}^{\pm}_1$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	$m(\tilde{\chi}^0_1)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}^0_1$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-210 GeV	$m(\tilde{\chi}^0_1)$ =$m(\tilde{t}_1)$-$m(W)$-50 GeV, $m(\tilde{t}_1)$<<$m(\tilde{\chi}^{\pm}_1)$	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}^0_1$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$ 215-530 GeV	$m(\tilde{\chi}^0_1)$=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}^{\pm}_1$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^{\pm}_1)$-$m(\tilde{\chi}^0_1)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}^0_1$	1 e,μ	1 b	Yes	20	$\tilde{t}_1$ 210-640 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1407.0583
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}^0_1$	0	2 b	Yes	20.1	$\tilde{t}_1$ 260-640 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1406.1122
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}^0_1$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-240 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}^0_1)$<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}^0_1)$>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	$m(\tilde{\chi}^0_1)$<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}^0_1$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1403.5294
	$\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^+_1\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}^{\pm}_1$ 140-465 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^{\pm}_1)+m(\tilde{\chi}^0_1))$	1403.5294
	$\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^+_1\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}^{\pm}_1$ 100-350 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}^{\pm}_1)+m(\tilde{\chi}^0_1))$	1407.0350
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 700 GeV	$m(\tilde{\chi}^{\pm}_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^{\pm}_1)+m(\tilde{\chi}^0_1))$	1402.7029
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1Z\tilde{\chi}^0_1$	2-3 e,μ	0	Yes	20.3	$\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 420 GeV	$m(\tilde{\chi}^{\pm}_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1h\tilde{\chi}^0_1$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 285 GeV	$m(\tilde{\chi}^{\pm}_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	ATLAS-CONF-2013-093
	$\tilde{\chi}^0_2\tilde{\chi}^0_3$, $\tilde{\chi}^0_{2,3}\to\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}^0_{2,3}$ 620 GeV	$m(\tilde{\chi}^0_2)=m(\tilde{\chi}^0_3)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^0_2)+m(\tilde{\chi}^0_1))$	1405.5086
Long-lived particles	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^{\pm}_1$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}^{\pm}_1$ 270 GeV	$m(\tilde{\chi}^{\pm}_1)$-$m(\tilde{\chi}^0_1)$=160 MeV, $\tau(\tilde{\chi}^{\pm}_1)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}^0_1)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}^0_1$ 475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	4.7	$\tilde{\chi}^0_1$ 230 GeV	0.4<$\tau(\tilde{\chi}^0_1)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}^0_1\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}^0_1)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q},\tilde{g}$ 1.35 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^+_1\to W\tilde{\chi}^0_1$, $\tilde{\chi}^0_1\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.3	$\tilde{\chi}^{\pm}_1$ 750 GeV	$m(\tilde{\chi}^0_1)$>0.2×$m(\tilde{\chi}^{\pm}_1)$, $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^+_1\to W\tilde{\chi}^0_1$, $\tilde{\chi}^0_1\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.3	$\tilde{\chi}^{\pm}_1$ 450 GeV	$m(\tilde{\chi}^0_1)$>0.2×$m(\tilde{\chi}^{\pm}_1)$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 850 GeV		1404.250
Other	Scalar gluon pair, sgluon→$q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon→$t\bar{t}$	2 e,μ (SS)	2 b	Yes	14.3	sgluon 350-800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Direct Stop ($\tilde{t}$) Search Summary





The RPV superpotential

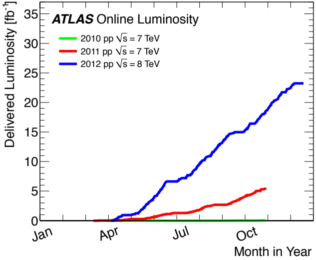
Direct decay of sparticles to SM particles can occur via in the R-parity violation (RPV) superpotential, $W_{\not{R}_p}$, via three general terms:

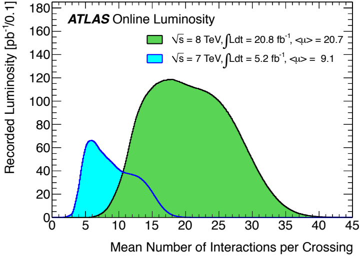
$$W_{\not{R}_p} = \boxed{\frac{1}{2}\lambda_{ijk}L_iL_j\bar{E}_k} + \boxed{\lambda'_{ijk}L_iQ_j\bar{D}_k} + \boxed{\frac{1}{2}\lambda''_{ijk}\bar{U}_i\bar{D}_j\bar{D}_k} + \boxed{\kappa_iL_iH_2}$$

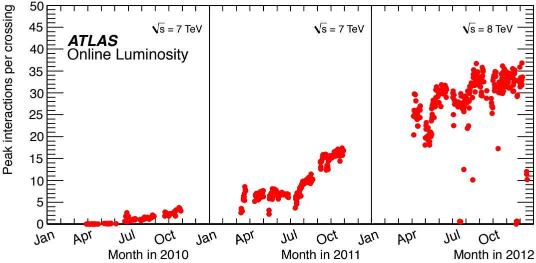
- Trilinear <u>baryon</u> number violating term: *UDD*

The *UDD* term is generally least constrained via collider experiments, in part because the all-hadronic decays are hard to constrain.

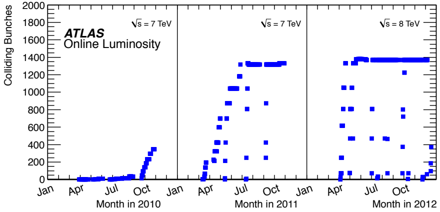
Luminosity in 2011 and 2012

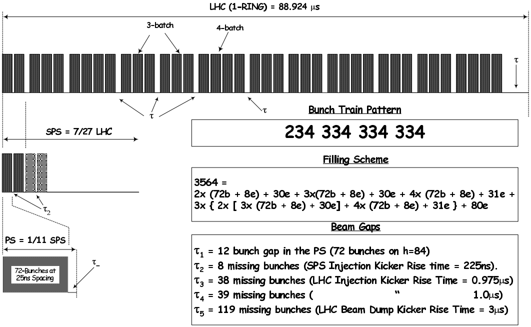






Bunch structure information





Bunch Train Pattern

234 334 334 334

Filling Scheme

3564 =
2x (72b + 8e) + 30e + 3x(72b + 8e) + 30e + 4x (72b + 8e) + 31e +
3x { 2x [3x (72b + 8e) + 30e] + 4x (72b + 8e) + 31e } + 80e

Beam Gaps

τ_1 = 12 bunch gap in the PS (72 bunches on h=84)
τ_2 = 8 missing bunches (SPS Injection Kicker Rise time = 225ns).
τ_3 = 38 missing bunches (LHC Injection Kicker Rise Time = 0.975μs)
τ_4 = 39 missing bunches (" 1.0μs)
τ_5 = 119 missing bunches (LHC Beam Dump Kicker Rise Time = 3μs)

Limits on λ''

From Barbier, et al. [5]

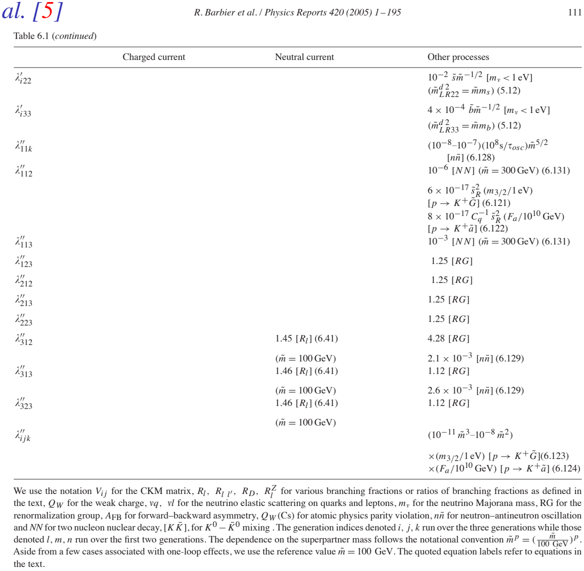


Table 6.1 (*continued*)

	Charged current	Neutral current	Other processes
λ'_{i22}			$10^{-2}\ \tilde{s}\tilde{m}^{-1/2}\ [m_\nu < 1\,\text{eV}]$ $(\tilde{m}^{d\,2}_{LR22} = \tilde{m}m_s)$ (5.12)
λ'_{i33}			$4 \times 10^{-4}\ \tilde{b}\tilde{m}^{-1/2}\ [m_\nu < 1\,\text{eV}]$ $(\tilde{m}^{d\,2}_{LR33} = \tilde{m}m_b)$ (5.12)
λ''_{11k}			$(10^{-8}\text{–}10^{-7})(10^8\text{s}/\tau_{osc})\tilde{m}^{5/2}$ $[n\bar{n}]$ (6.128)
λ''_{112}			$10^{-6}\ [NN]\ (\tilde{m} = 300\,\text{GeV})$ (6.131) $6 \times 10^{-17}\,\tilde{s}^2_R\,(m_{3/2}/1\,\text{eV})$ $[p \to K^+\tilde{G}]$ (6.121) $8 \times 10^{-17}\,C_q^{-1}\,\tilde{s}^2_R\,(F_a/10^{10}\,\text{GeV})$ $[p \to K^+\tilde{a}]$ (6.122)
λ''_{113}			$10^{-3}\ [NN]\ (\tilde{m} = 300\,\text{GeV})$ (6.131)
λ''_{123}			1.25 $[RG]$
λ''_{212}			1.25 $[RG]$
λ''_{213}			1.25 $[RG]$
λ''_{223}			1.25 $[RG]$
λ''_{312}		1.45 $[R_l]$ (6.41) $(\tilde{m} = 100\,\text{GeV})$	4.28 $[RG]$ $2.1 \times 10^{-3}\ [n\bar{n}]$ (6.129)
λ''_{313}		1.46 $[R_l]$ (6.41) $(\tilde{m} = 100\,\text{GeV})$	1.12 $[RG]$ $2.6 \times 10^{-3}\ [n\bar{n}]$ (6.129)
λ''_{323}		1.46 $[R_l]$ (6.41) $(\tilde{m} = 100\,\text{GeV})$	1.12 $[RG]$
λ''_{ijk}			$(10^{-11}\,\tilde{m}^3\text{–}10^{-8}\,\tilde{m}^2)$ $\times(m_{3/2}/1\,\text{eV})\ [p \to K^+\tilde{G}]$(6.123) $\times(F_a/10^{10}\,\text{GeV})\ [p \to K^+\tilde{a}]$ (6.124)

We use the notation V_{ij} for the CKM matrix, $R_l,\ R_{l\,l'},\ R_D,\ R^Z_l$ for various branching fractions or ratios of branching fractions as defined in the text, Q_W for the weak charge, $\nu q,\ \nu l$ for the neutrino elastic scattering on quarks and leptons, m_ν for the neutrino Majorana mass, RG for the renormalization group, A_{FB} for forward–backward asymmetry, $Q_W(\text{Cs})$ for atomic physics parity violation, $n\bar{n}$ for neutron–antineutron oscillation and NN for two nucleon nuclear decay, $[K\bar{K}]$, for $K^0 - \bar{K}^0$ mixing . The generation indices denoted $i,\ j,\ k$ run over the three generations while those denoted l, m, n run over the first two generations. The dependence on the superpartner mass follows the notational convention $\tilde{m}^p = (\frac{\tilde{m}}{100\ \text{GeV}})^p$. Aside from a few cases associated with one-loop effects, we use the reference value $\tilde{m} = 100$ GeV. The quoted equation labels refer to equations in the text.

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