Mini Review- Supersymmetry phenomenology at the LHC

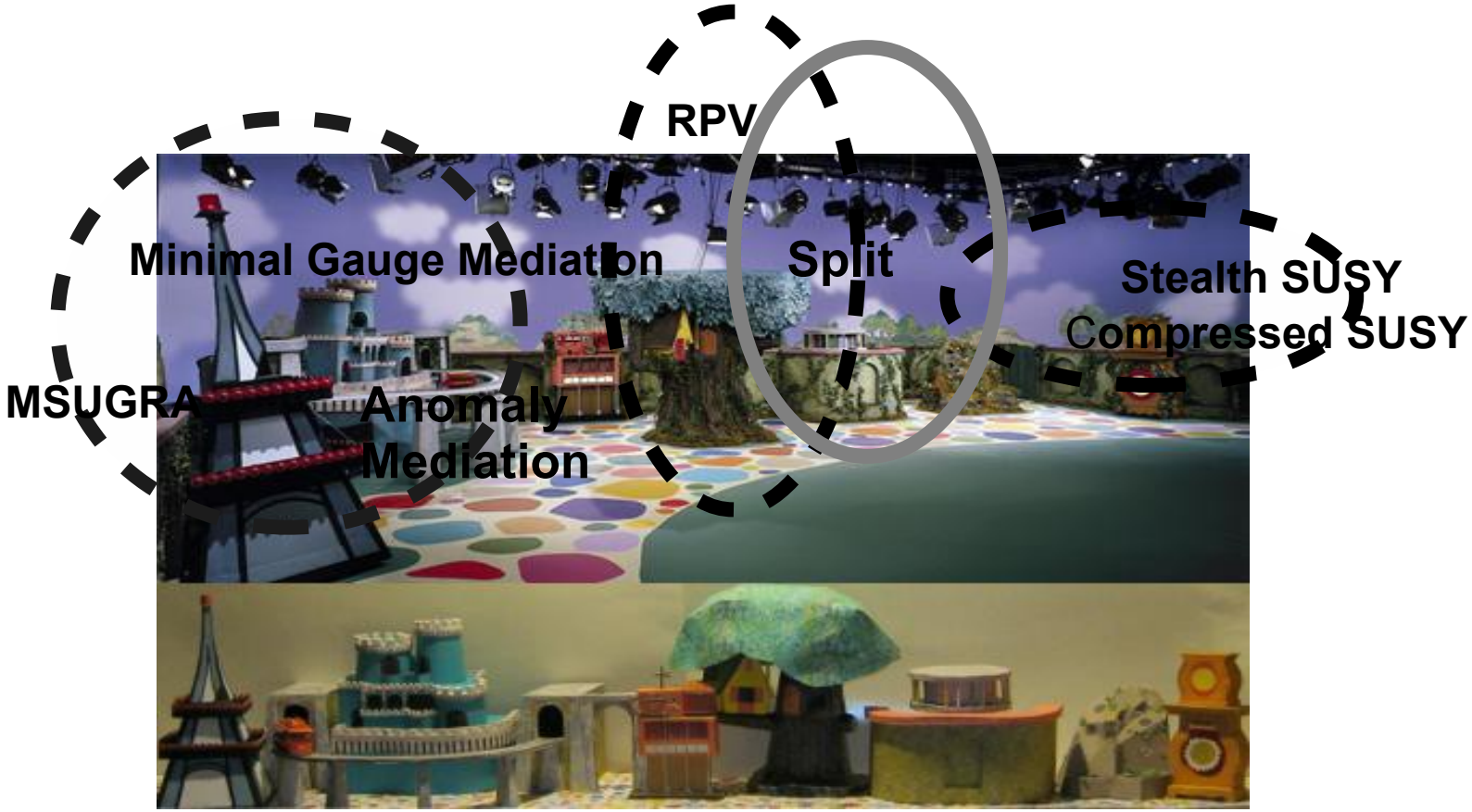
Linda Carpenter- Ohio State

PHENO
2017@ U PITT

SUSY

- Contains Poincare Algebra
- Makes a light Higgs mass natural with order by order cancellations
- Gauge coupling unification
- Possible DM candidate

Explore SUSY Models



The Elegant but Perhaps too Simplistic

Correct as Usual

Minimal models with standard smoking gun signatures

- Minimal Gauge Mediation
- MSUGRA standard benchmarks
- Minimal Anomaly Mediation

Signatures

Jets plus MET w/ lepton veto
Trileptons+MET
Large mass splittins w/ nearly massless LSP

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2017

ATLAS Preliminary

$\sqrt{s}$ = 7, 8, 13 TeV

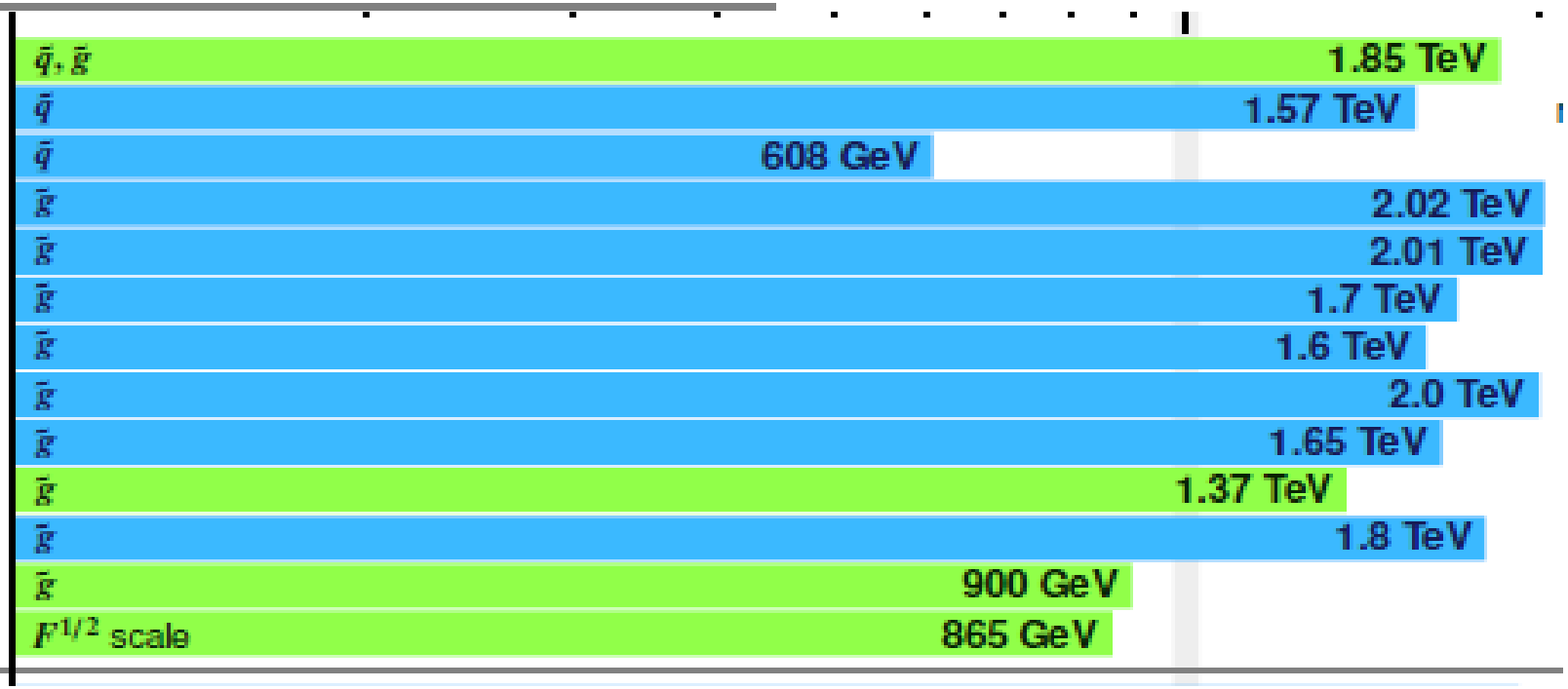
$\sqrt{s}$ = 7, 8 TeV | $\sqrt{s}$ = 13 TeV

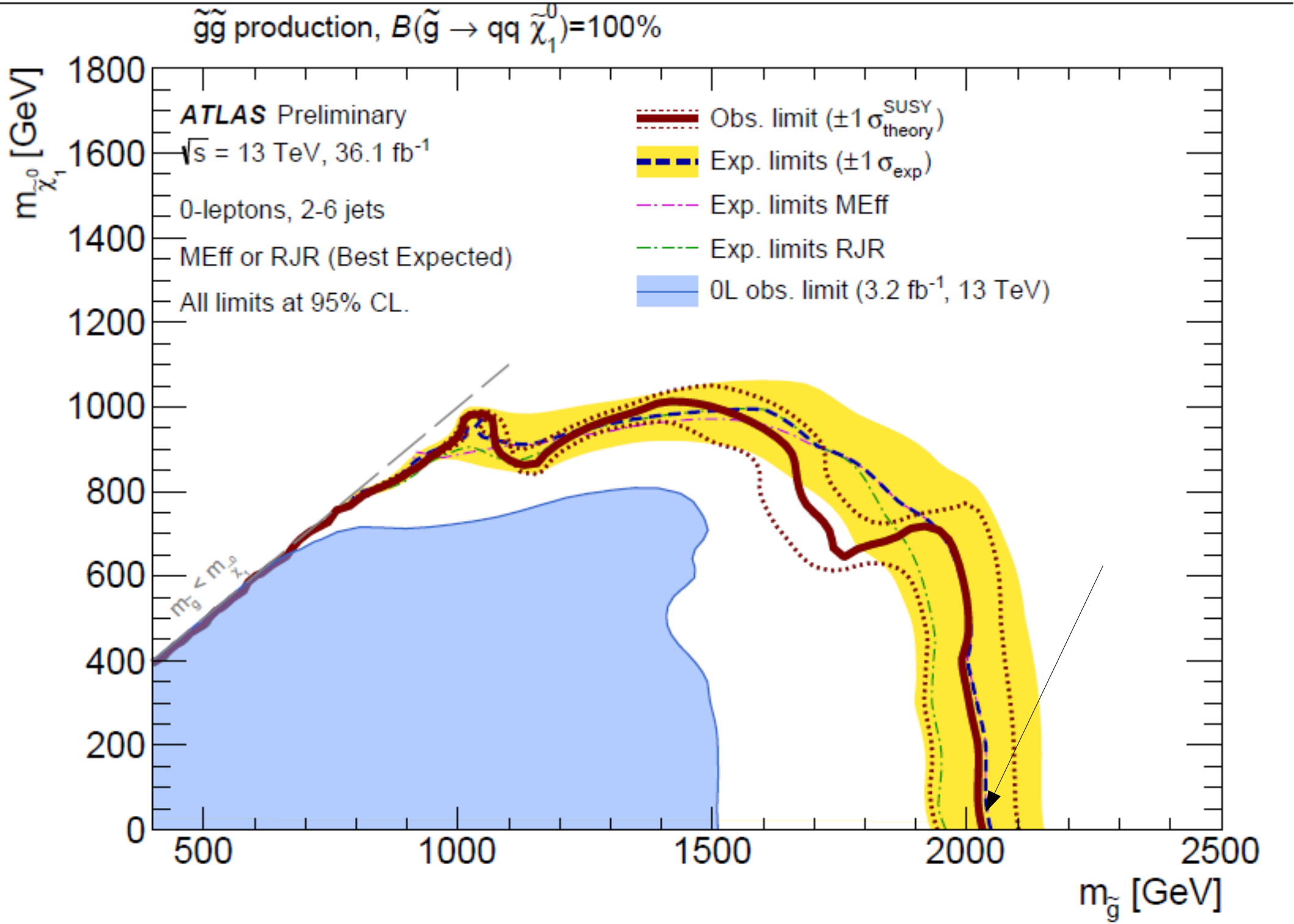
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e, μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.85 TeV	$m(\tilde{q})=m(\tilde{g})$	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{q}$ 1.57 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	ATLAS-CONF-2017-022
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$ 608 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0)$<5 GeV	1604.07773
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{g}$ 2.02 TeV	$m(\tilde{\chi}_1^0)$<200 GeV	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{g}$ 2.01 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\nu\nu)\tilde{\chi}_1^0$	3 e, μ	4 jets	-	13.2	$\tilde{g}$ 1.7 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2016-037
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}_1^0$	2 e, μ (SS)	0-3 jets	Yes	13.2	$\tilde{g}$ 1.6 TeV	$m(\tilde{\chi}_1^0)$ <500 GeV	ATLAS-CONF-2016-037
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	$\tilde{g}$ 2.0 TeV		1607.05979
	GGM (bino NLSP)	2 γ	-	Yes	3.2	$\tilde{g}$ 1.65 TeV	$c\tau$(NLSP)<0.1 mm	1606.09150
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}_1^0)$<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	$\tilde{g}$ 1.8 TeV	$m(\tilde{\chi}_1^0)$>680 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	ATLAS-CONF-2016-066
	GGM (higgsino NLSP)	2 e, μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	36.1	$\tilde{g}$ 1.92 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	36.1	$\tilde{g}$ 1.97 TeV	$m(\tilde{\chi}_1^0)$<200 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	3.2	$\tilde{b}_1$ 840 GeV	$m(\tilde{\chi}_1^0)$<100 GeV	1606.08772
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	1 b	Yes	13.2	$\tilde{b}_1$ 325-685 GeV	$m(\tilde{\chi}_1^0)$<150 GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$+100 GeV	ATLAS-CONF-2016-037
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}_1^\pm$	0-2 e, μ	1-2 b	Yes	4.7/13.3	$\tilde{t}_1$ 117-170 GeV, 200-720 GeV	$m(\tilde{\chi}_1^\pm)=2m(\tilde{\chi}_1^0)$, $m(\tilde{\chi}_1^0)$=55 GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e, μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 90-198 GeV, 205-950 GeV	$m(\tilde{\chi}_1^0)$=1 GeV	1506.08616, ATLAS-CONF-2017-020
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet	Yes	3.2	$\tilde{t}_1$ 90-323 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$=5 GeV	1604.07773
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-600 GeV	$m(\tilde{\chi}_1^0)$>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	36.1	$\tilde{t}_2$ 290-790 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2017-019
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+h$	1-2 e, μ	4 b	Yes	36.1	$\tilde{t}_2$ 320-880 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2017-019
EW direct	$\tilde{\ell}_{1,R}\tilde{\ell}_{1,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$ 90-335 GeV	$m(\tilde{\chi}_1^0)$=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	13.3	$\tilde{\chi}_1^\pm$ 640 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2016-096
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	14.8	$\tilde{\chi}_1^\pm$ 580 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2016-093
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	13.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 1.0 TeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2016-096
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	2-3 e, μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 425 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $\tilde{\ell}$ decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 270 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $\tilde{\ell}$ decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 635 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
	GGM (wino NLSP) weak prod.	1 e, μ + γ	-	Yes	20.3	$\tilde{W}$ 115-370 GeV	$c\tau$<1 mm	1507.05493
	GGM (bino NLSP) weak prod.	2 γ	-	Yes	20.3	$\tilde{W}$ 590 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	36.1	$\tilde{\chi}_1^\pm$ 430 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2017-017
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^\pm$ 495 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^\pm)$<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 850 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	3.2	$\tilde{g}$ 1.58 TeV		1606.05129
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	$\tilde{g}$ 1.57 TeV	$m(\tilde{\chi}_1^0)$=100 GeV, τ>10 ns	1604.04520
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 440 GeV	1<$\tau(\tilde{\chi}_1^0)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7 <$c\tau(\tilde{\chi}_1^0)$< 740 mm, $m(\tilde{g})$=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	6 <$c\tau(\tilde{\chi}_1^0)$< 480 mm, $m(\tilde{g})$=1.1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu, e\tau, \mu\tau$	-	-	3.2	$\tilde{\nu}_\tau$ 1.9 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.45 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\nu, e\mu\nu, \mu\mu\nu$	4 e, μ	-	Yes	13.3	$\tilde{\chi}_1^\pm$ 1.14 TeV	$m(\tilde{\chi}_1^0)$>400GeV, $\lambda_{12k}\neq0$ (k = 1, 2)	ATLAS-CONF-2016-075
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\nu_e, e\tau\nu_\tau$	3 e, μ + τ	-	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
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	4-5 large-R jets	-	14.8	$\tilde{g}$ 1.08 TeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	0	4-5 large-R jets	-	14.8	$\tilde{g}$ 1.55 TeV	$m(\tilde{\chi}_1^0)$=800 GeV	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	1 e, μ	8-10 jets/0-4 b	-	36.1	$\tilde{g}$ 2.1 TeV	$m(\tilde{\chi}_1^0)$= 1 TeV, $\lambda_{112}\neq0$	ATLAS-CONF-2017-013
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1t, \tilde{t}_1\to bs$	1 e, μ	8-10 jets/0-4 b	-	36.1	$\tilde{g}$ 1.65 TeV	$m(\tilde{t}_1)$= 1 TeV, $\lambda_{323}\neq0$	ATLAS-CONF-2017-013
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	15.4	$\tilde{t}_1$ 410 GeV, 450-510 GeV		ATLAS-CONF-2016-022, ATLAS-CONF-2016-084
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e, μ	2 b	-	20.3	$\tilde{t}_1$ 0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 510 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1501.01325

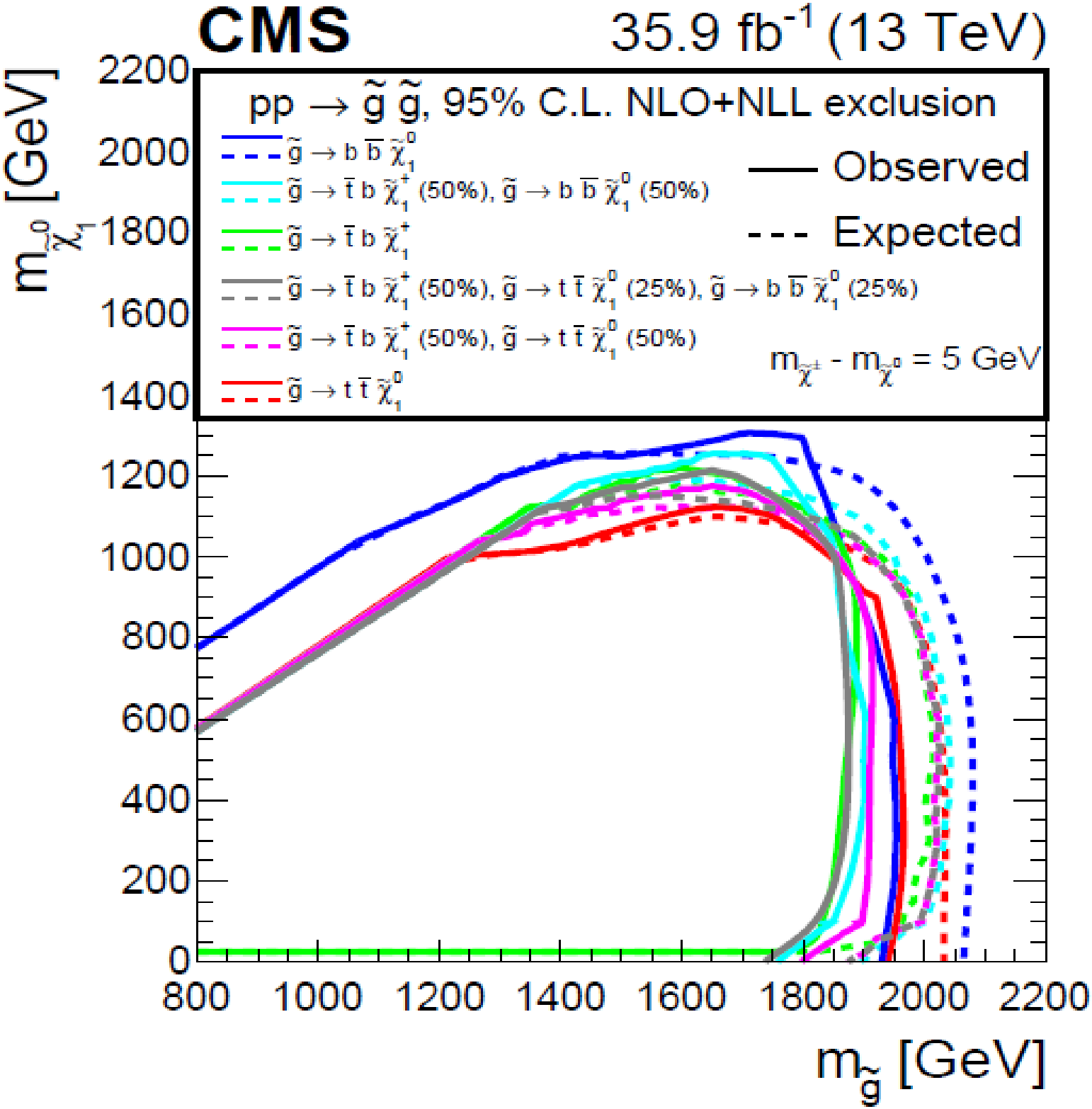
10^{-1} — 1 — Mass scale [TeV]

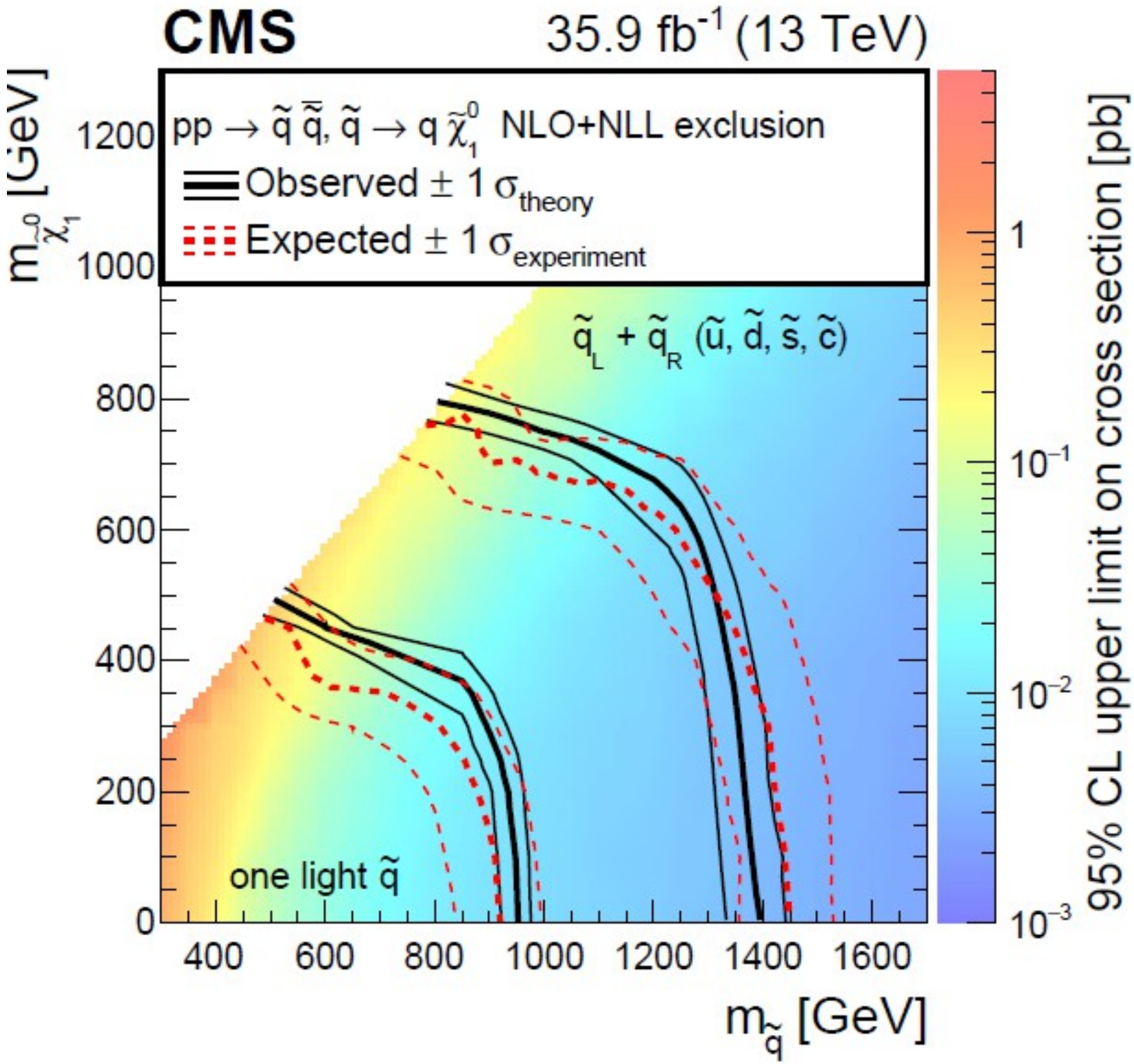
*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

Inclusive Searches			
	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	0	2-6 jets
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\nu\nu)\tilde{\chi}_1^0$	3 e,μ	4 jets
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qqWZ\tilde{\chi}_1^0$	2 e,μ (SS)	0-3 jets
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets
	GGM (bino NLSP)	2 γ	-
	GGM (higgsino-bino NLSP)	γ	1 b
	GGM (higgsino-bino NLSP)	γ	2 jets
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets
	Gravitino LSP	0	mono-jet



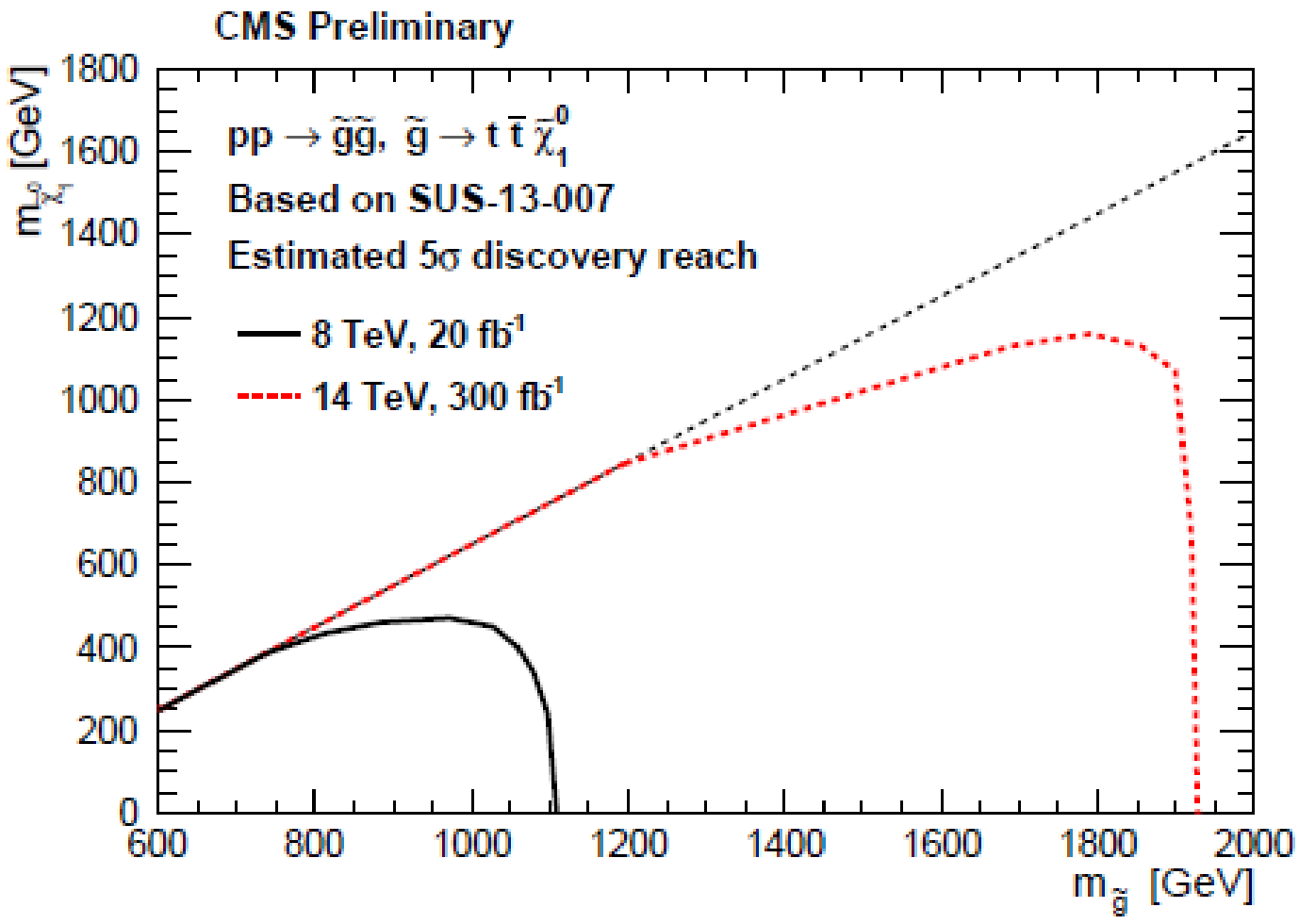

$\tilde{g}\tilde{g}$ production, $B(\tilde{g} \rightarrow qq\,\tilde{\chi}_1^0)$=100%
ATLAS Preliminary
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
0-leptons, 2-6 jets
MEff or RJR (Best Expected)
All limits at 95% CL.
Obs. limit ($\pm 1\,\sigma^{SUSY}_{theory}$)
Exp. limits ($\pm 1\,\sigma_{exp}$)
Exp. limits MEff
Exp. limits RJR
0L obs. limit (3.2 fb^{-1}, 13 TeV)
$m_{\tilde{g}} < m_{\tilde{\chi}_1^0}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{g}}$ [GeV]
0
200
400
600
800
1000
1200
1400
1600
1800
500
1000
1500
2000
2500


CMS
35.9 fb^{-1} (13 TeV)
pp → g̃ g̃, 95% C.L. NLO+NLL exclusion
g̃ → b b̄ χ̃$^0_1$
g̃ → t̄ b χ̃$^+_1$ (50%), g̃ → b b̄ χ̃$^0_1$ (50%)
g̃ → t̄ b χ̃$^+_1$
g̃ → t̄ b χ̃$^+_1$ (50%), g̃ → t t̄ χ̃$^0_1$ (25%), g̃ → b b̄ χ̃$^0_1$ (25%)
g̃ → t̄ b χ̃$^+_1$ (50%), g̃ → t t̄ χ̃$^0_1$ (50%)
g̃ → t t̄ χ̃$^0_1$
Observed
Expected
$m_{\tilde{\chi}^\pm} - m_{\tilde{\chi}^0}$ = 5 GeV
$m_{\tilde{\chi}^0_1}$ [GeV]
$m_{\tilde{g}}$ [GeV]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
800
1000
1200
1400
1600
1800
2000
2200

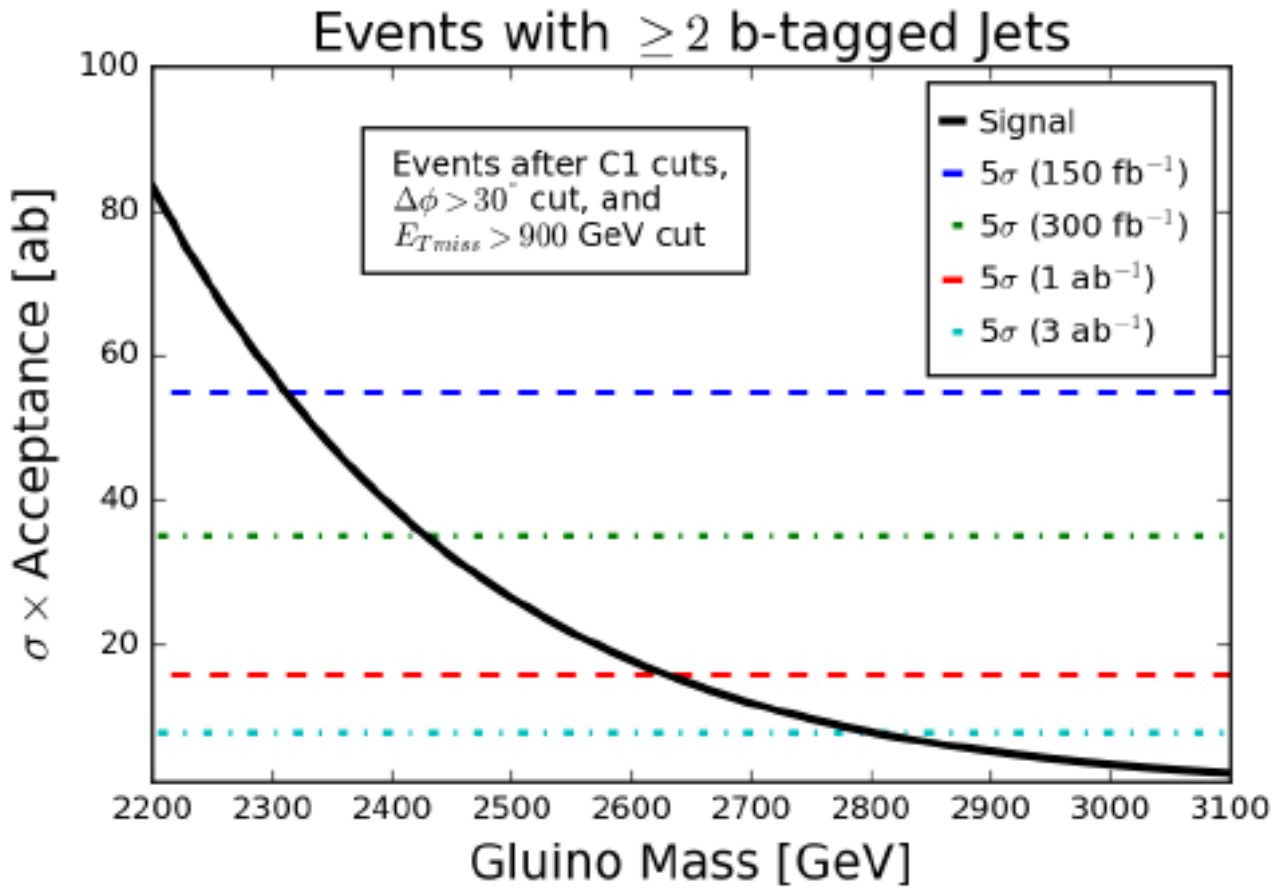

CMS
35.9 fb^{-1} (13 TeV)
$pp \to \tilde{q}\,\bar{\tilde{q}},\ \tilde{q} \to q\,\tilde{\chi}_1^0$ NLO+NLL exclusion
Observed $\pm$ 1 σ_{theory}
Expected $\pm$ 1 $\sigma_{experiment}$
$\tilde{q}_L + \tilde{q}_R$ ($\tilde{u}$, $\tilde{d}$, $\tilde{s}$, $\tilde{c}$)
one light $\tilde{q}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{q}}$ [GeV]
95% CL upper limit on cross section [pb]
0
200
400
600
800
1000
1200
400
600
800
1000
1200
1400
1600
1
10^{-1}
10^{-2}
10^{-3}

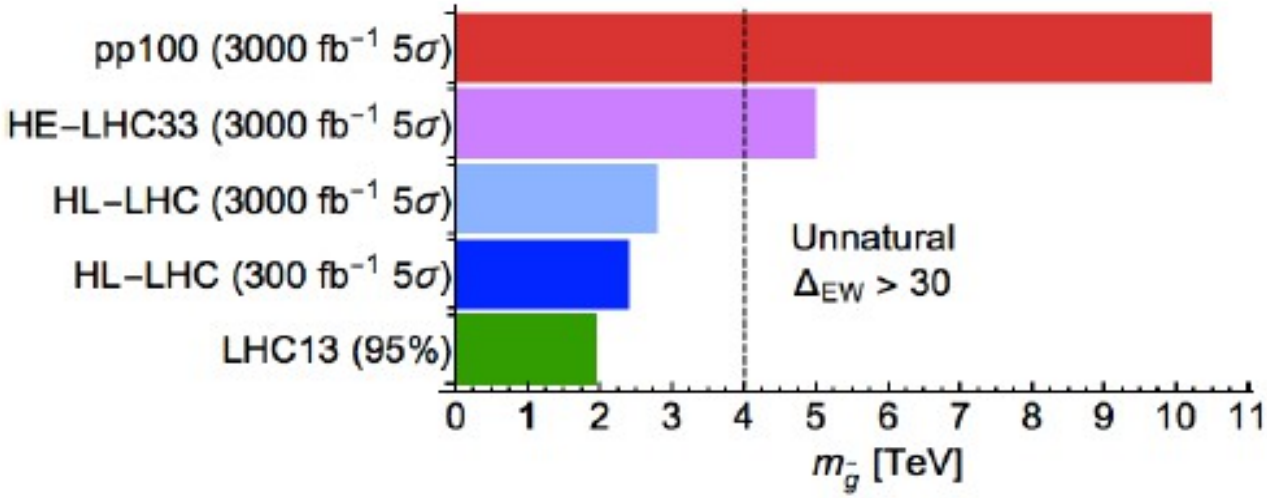
Discovery Limit

CMS collaboration "Future Sensitivity Studies for Supersymmetry Searches at CMS at 14 TeV" CMS-CR-2013-255



arXiv:1612.00795v1





Exploring Other Models

Correct as ~~Usual~~ Sometimes

The Shy

(Ultra)/Compressed Spectra

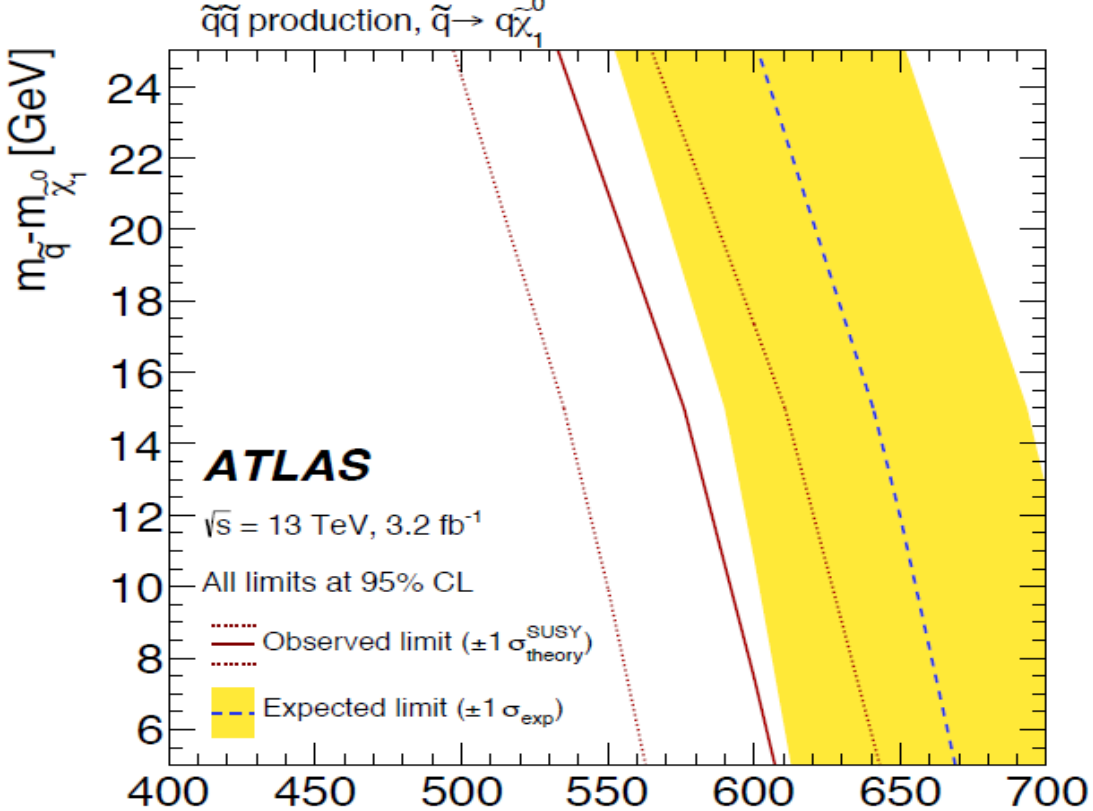
Stealth SUSY
Higgsino/Wino LSP
General Gauge Mediation
Split SUSY/Higgsino-World
RNS

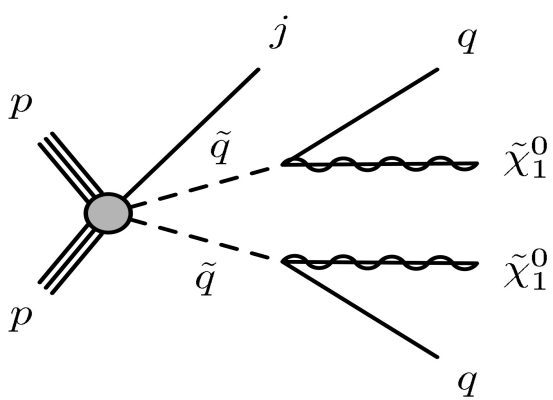
Signatures

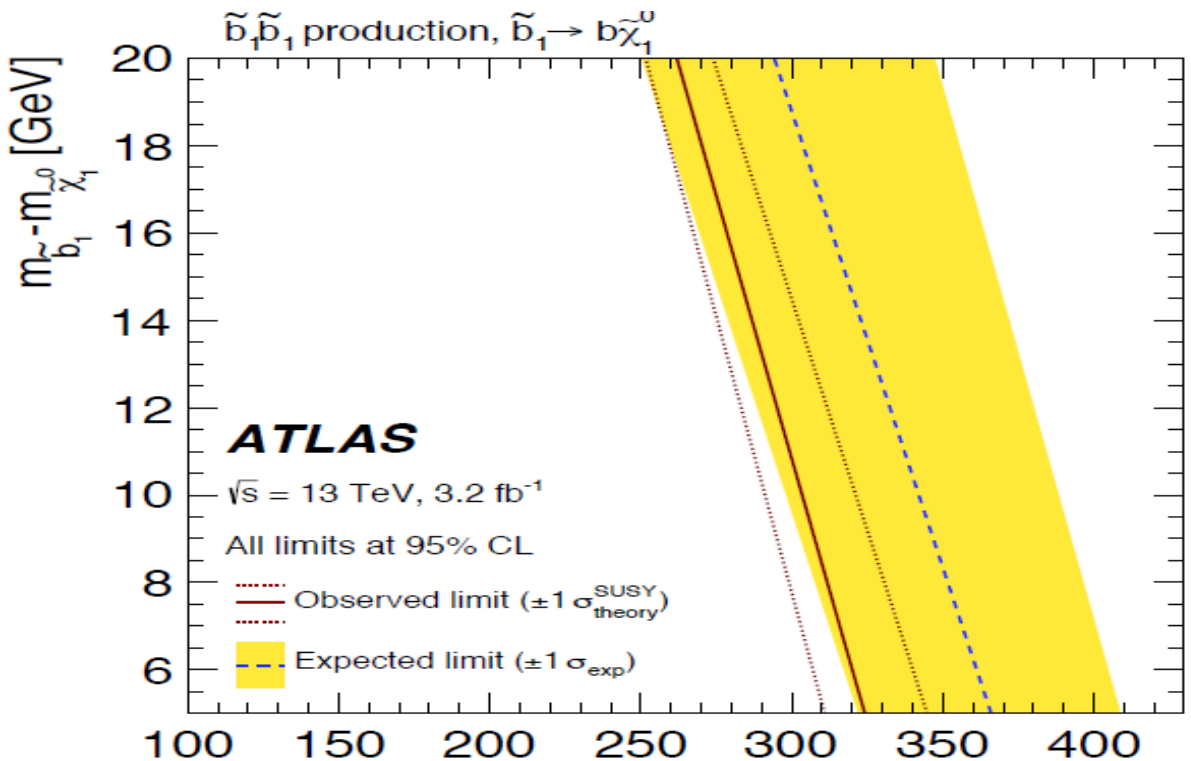
Mono-X searches
Searches w/low ET cuts

Phys. Rev. D 94 (2016) 032005

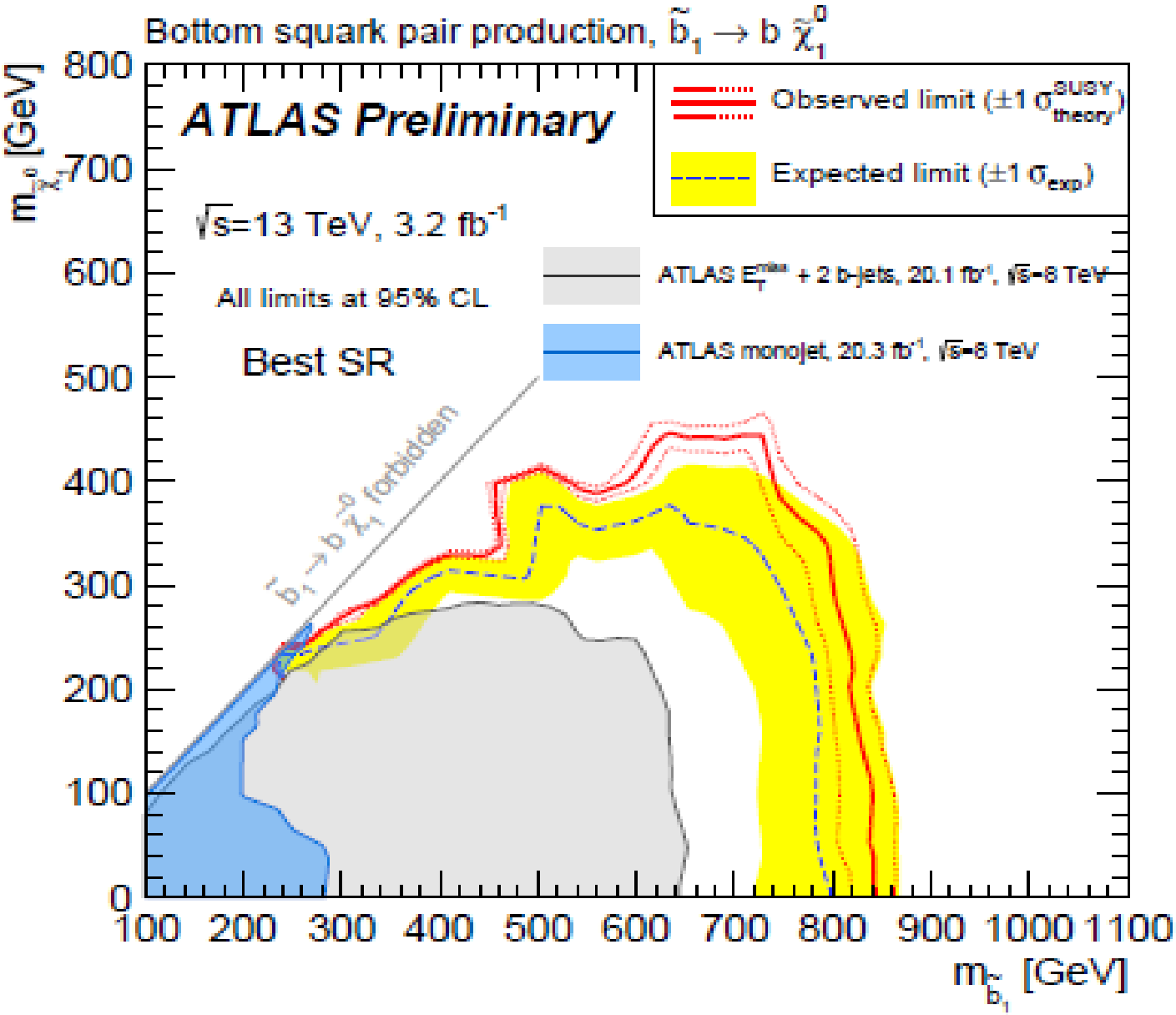
Mono-Mania



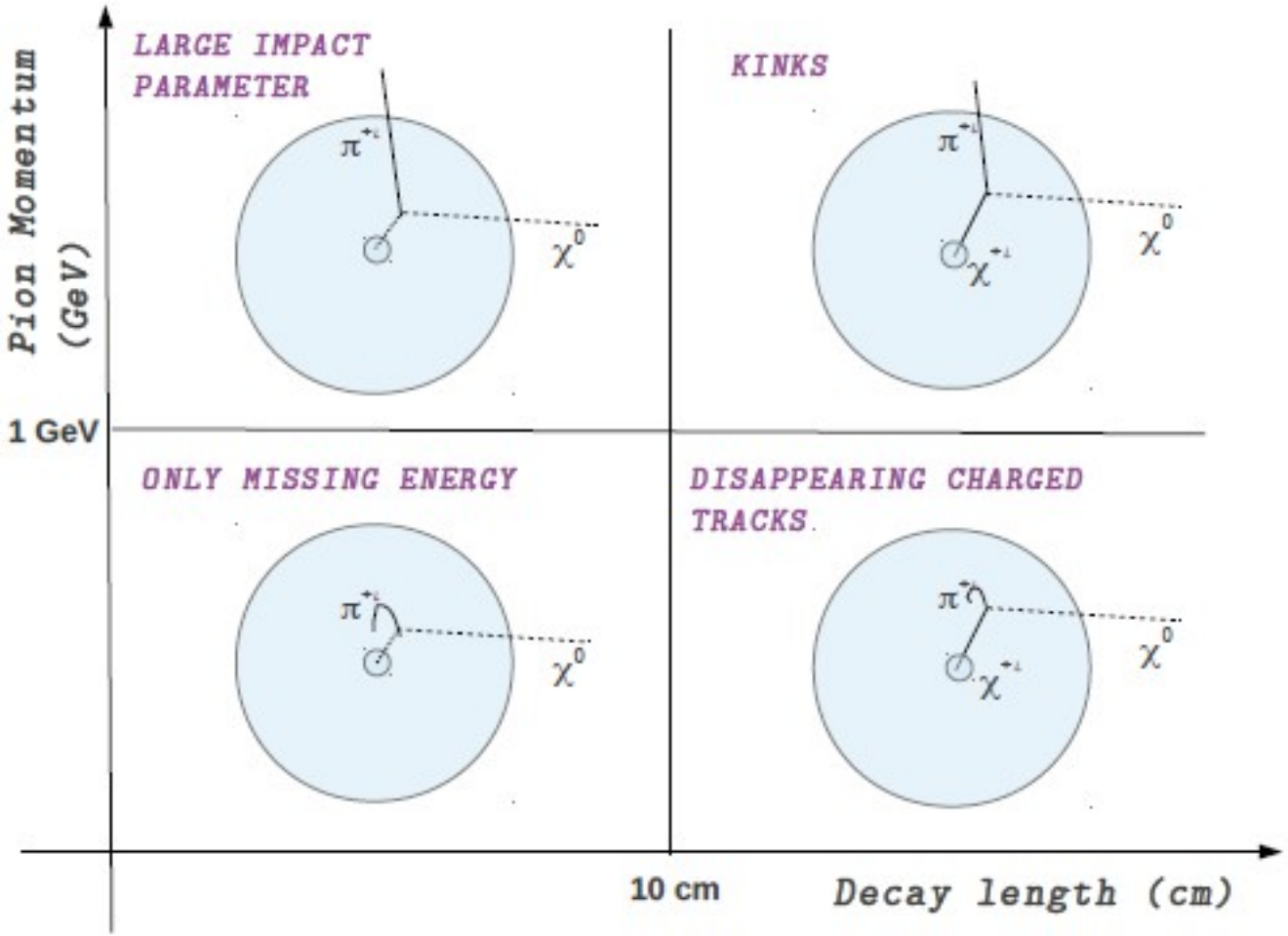




From “Compressed and Stealth SUSY searches with ATLAS and CMS”

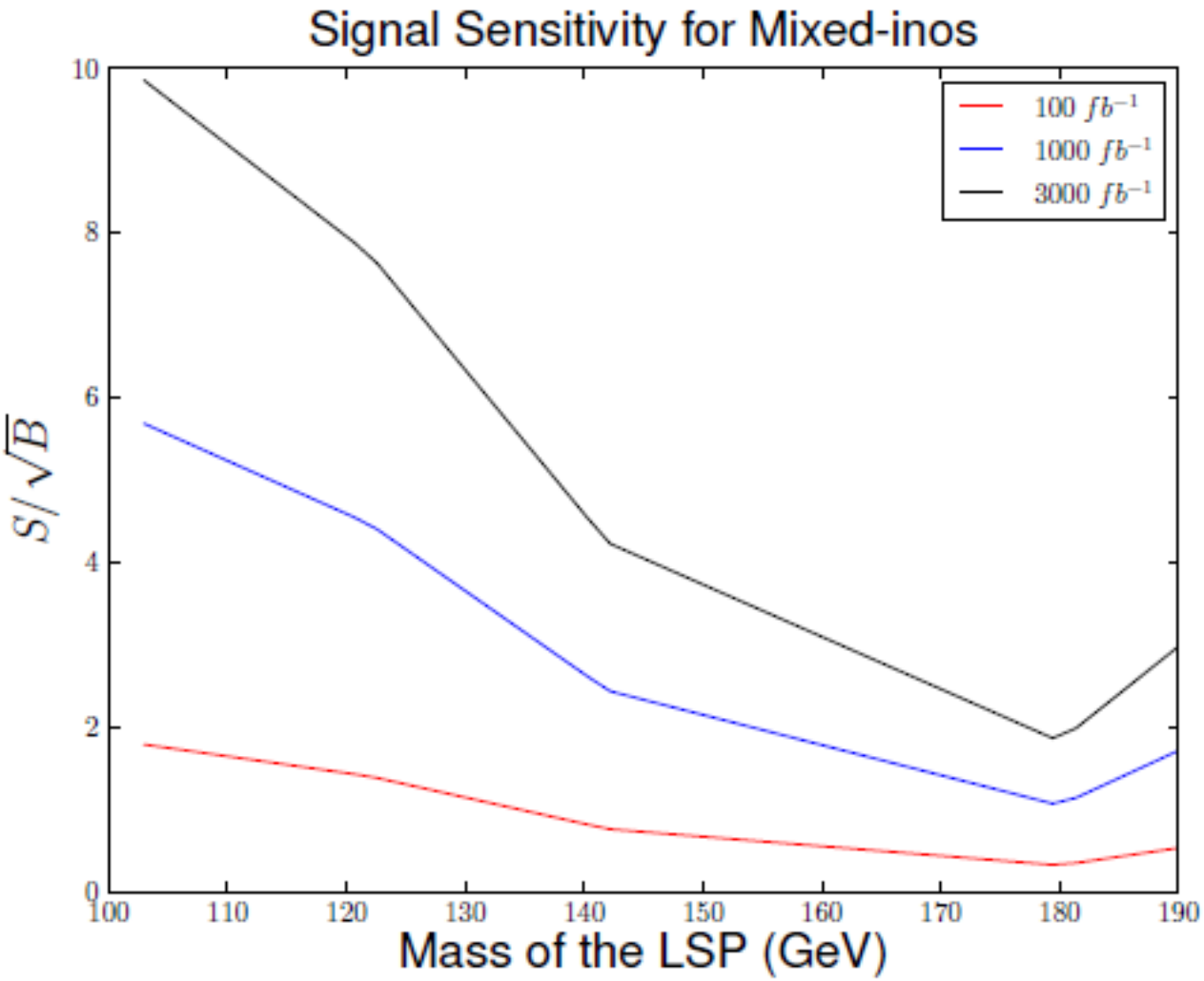


Higgsino/Wino LSP



arXiv:1407:1833

Mono-Z



(c) Mixed wino-higgsino LSP

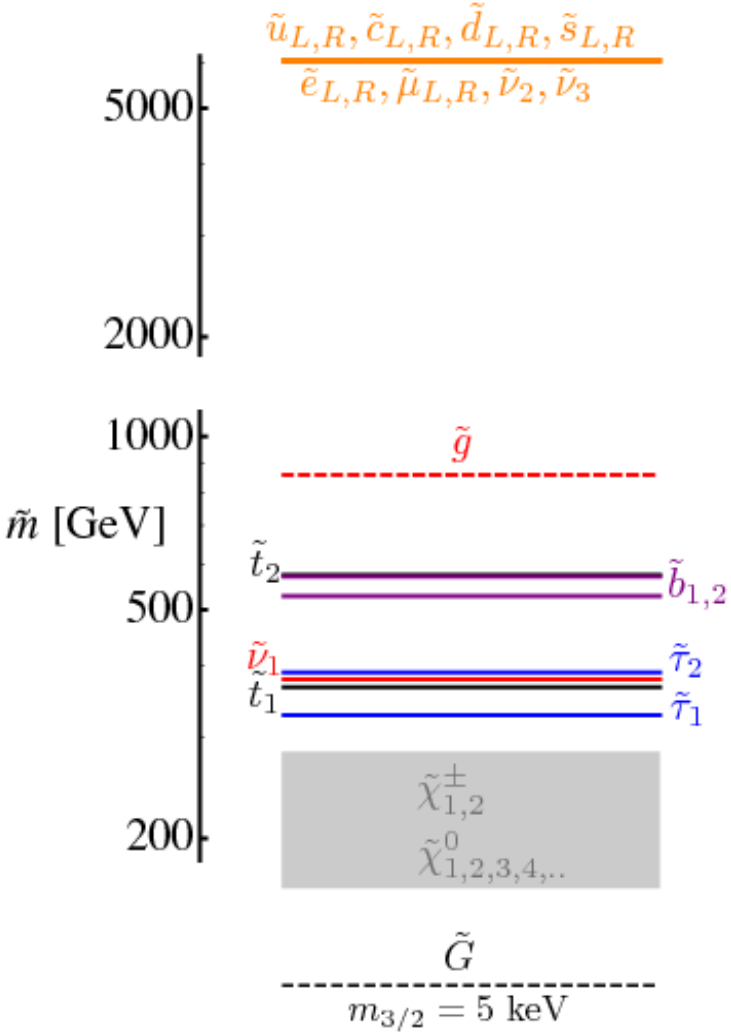
The weird/unusual/uncomfortable

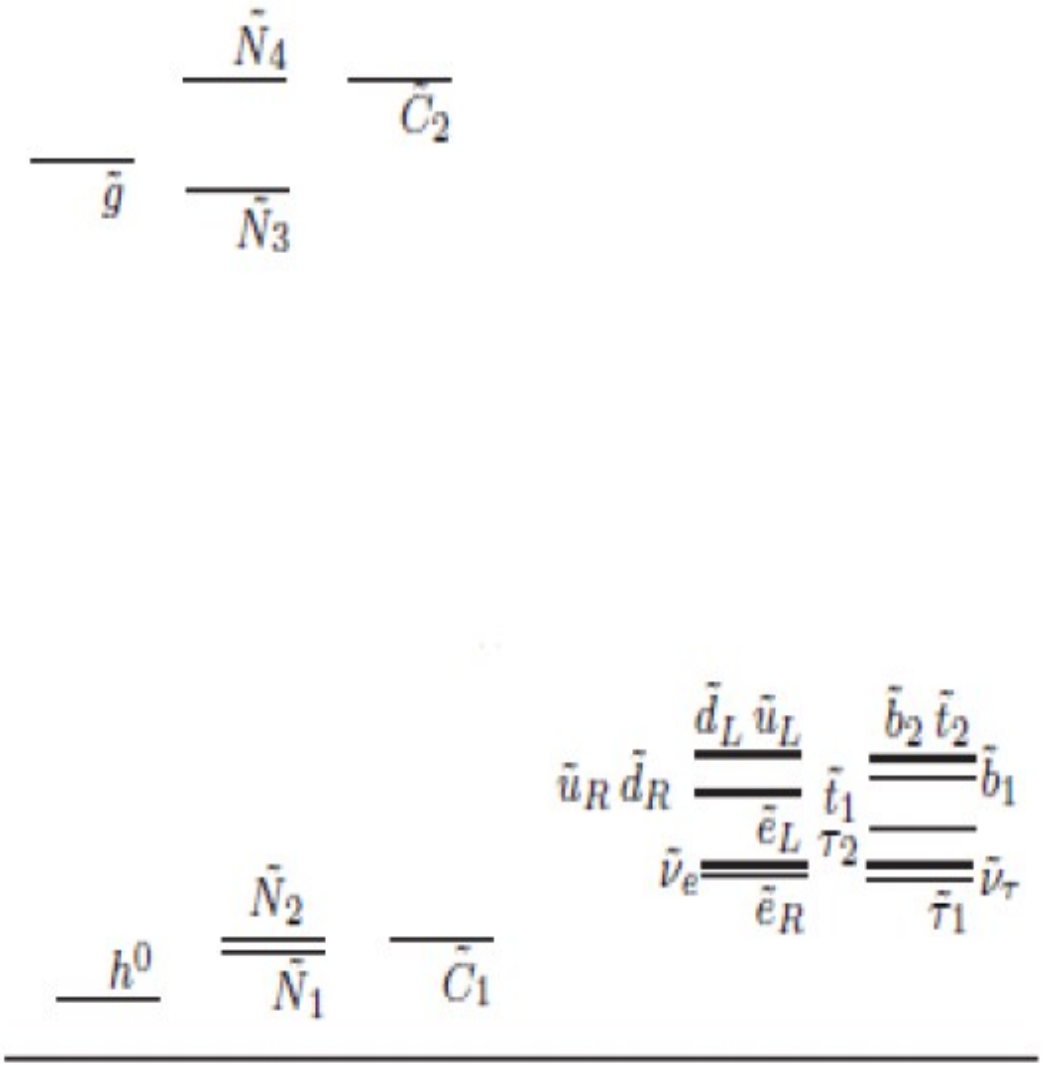
Get used to it Toots

Split SUSY
Mini-Split
Supersoft/Dirac Gauginos
Anti-split

Long Lived Particle
Displaced Vertices,
Kinks/dissappearing tracks
Bizzarre Decay Chains
Compressed Spectra

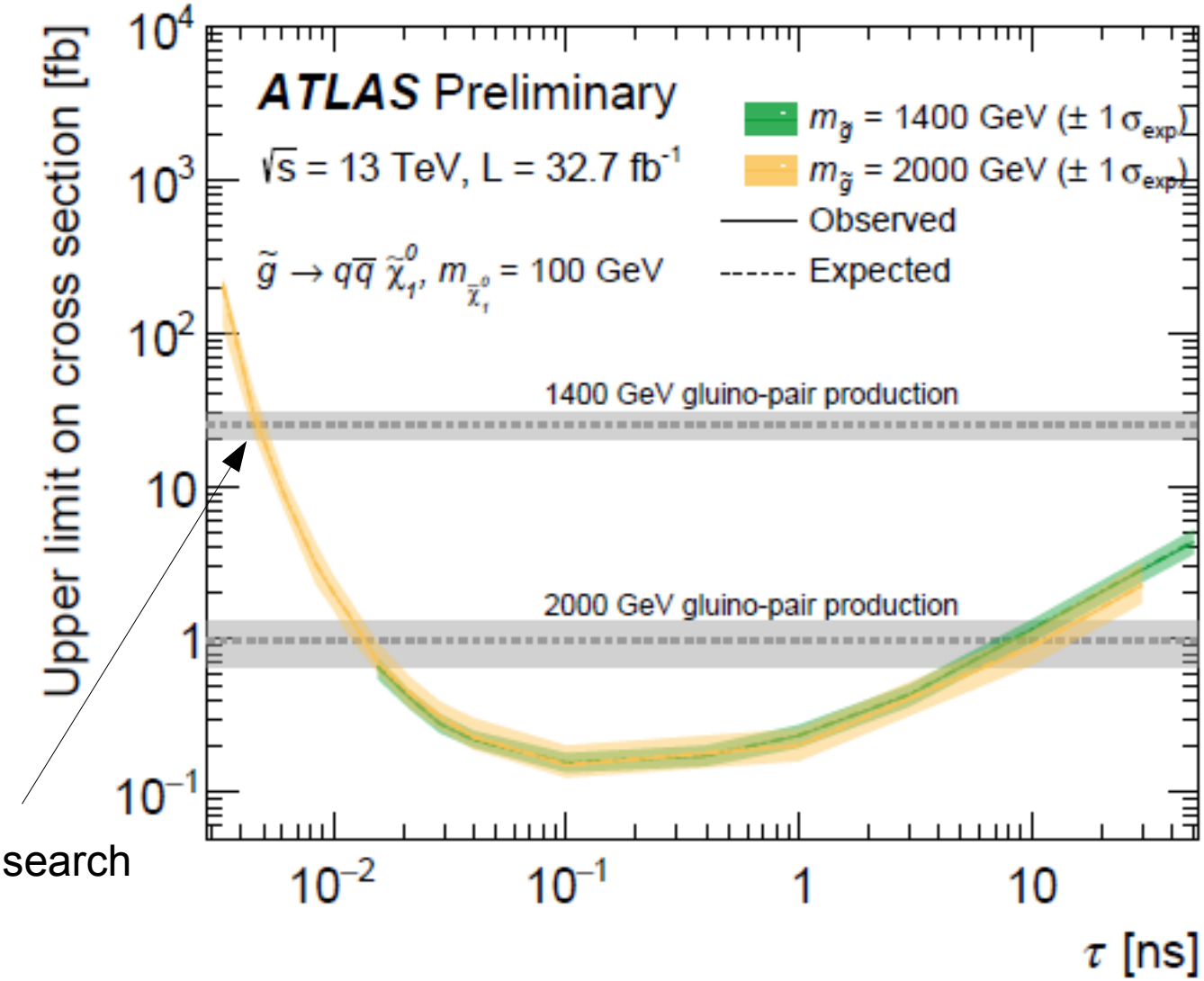
Split vs: Anti-split





arXiv:1203.1622

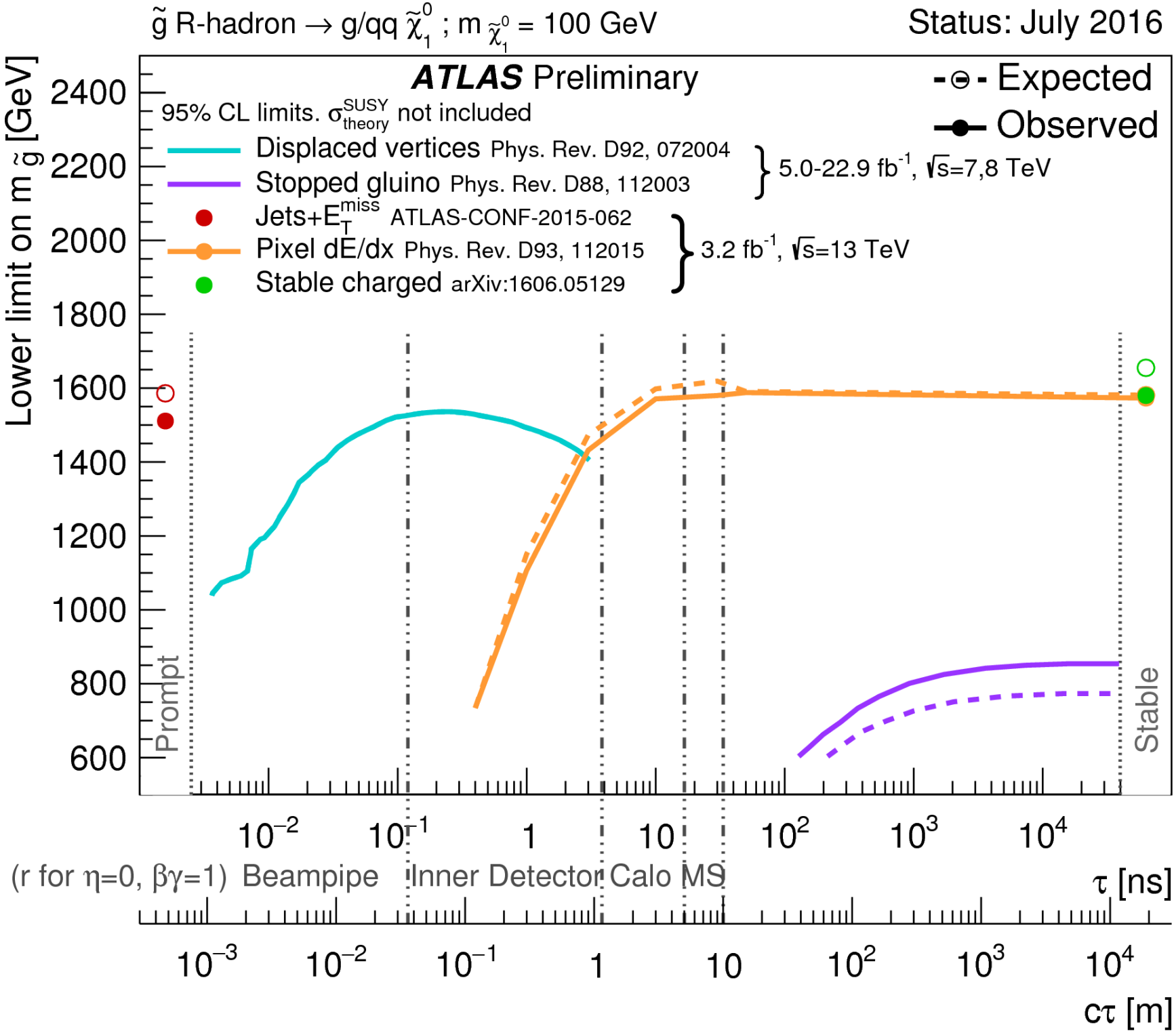
arXiv:1612.09255



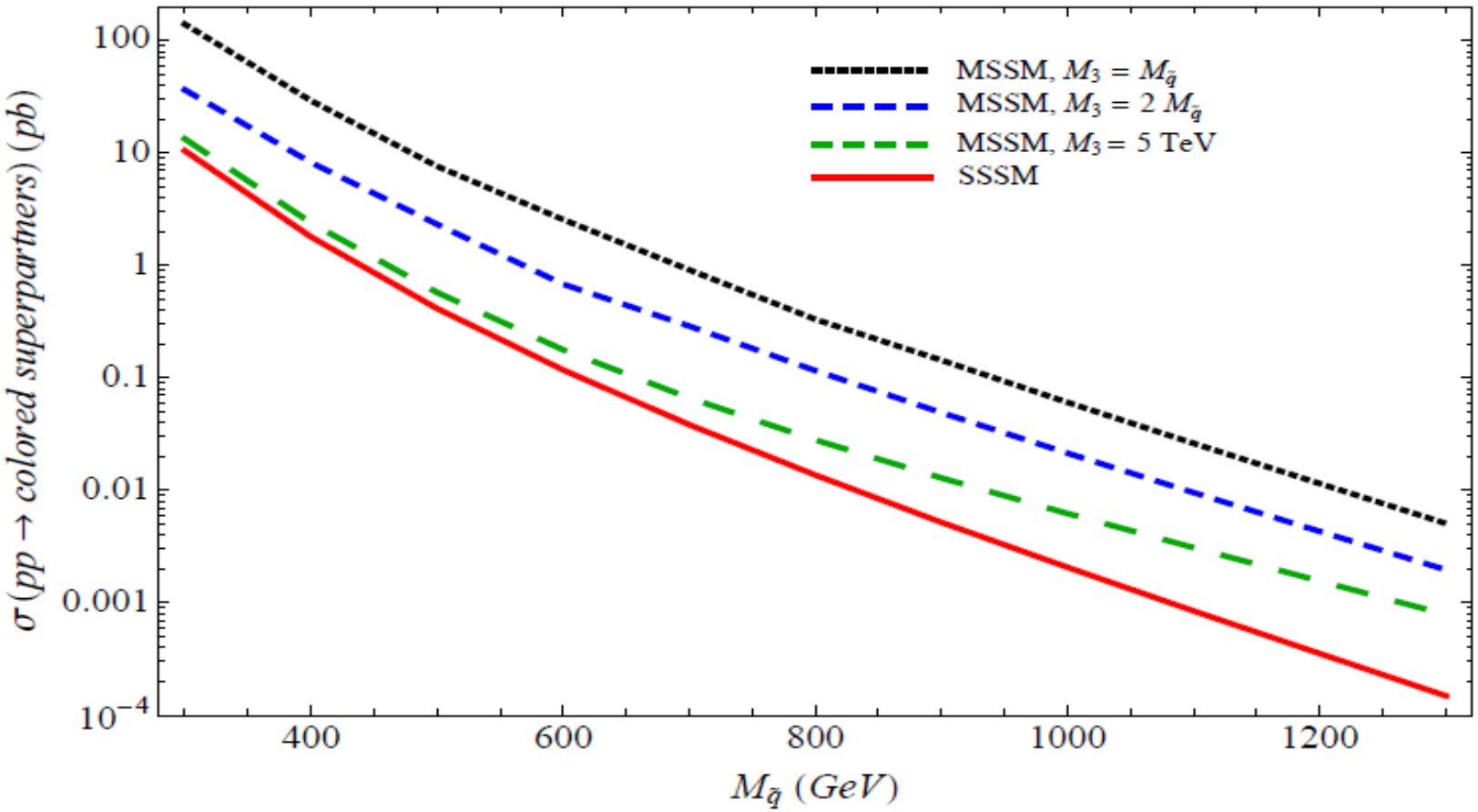
Note loss of search sensitivity

Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in sqrt s = 13 TeV p p collisions with the ATLAS detector

ATLAS-CONF-2017-026
ATLAS-CONF-2017-026


$\tilde{g}$ R-hadron → g/qq $\tilde{\chi}_1^0$; m $_{\tilde{\chi}_1^0}$ = 100 GeV
Status: July 2016
ATLAS Preliminary
95% CL limits. σ^{SUSY}_{theory} not included
Expected
Observed
Displaced vertices Phys. Rev. D92, 072004
Stopped gluino Phys. Rev. D88, 112003
5.0-22.9 fb^{-1}, $\sqrt{s}$=7,8 TeV
Jets+E_T^{miss} ATLAS-CONF-2015-062
Pixel dE/dx Phys. Rev. D93, 112015
Stable charged arXiv:1606.05129
3.2 fb^{-1}, $\sqrt{s}$=13 TeV
Lower limit on m $\tilde{g}$ [GeV]
2400
2200
2000
1800
1600
1400
1200
1000
800
600
Prompt
Stable
10^{-2}
10^{-1}
1
10
10^2
10^3
10^4
(r for η=0, βγ=1) Beampipe Inner Detector Calo MS
τ [ns]
10^{-3}
10^{-2}
10^{-1}
1
10
10^2
10^3
10^4
cτ [m]

Anti-split suppressed colored particle production



From “Supersoft is Supersafe” arXiv:12034821

Gluinos are not kinematically accessible and squark production in suppressed

May implement in General Gauge Mediation variant

various NLSP(stau, sneutrino, Higgsino)

Possible long lifetime of NLSP

Unique decay chains

Suppressed Bounds from colored particle production

Light stau scenario

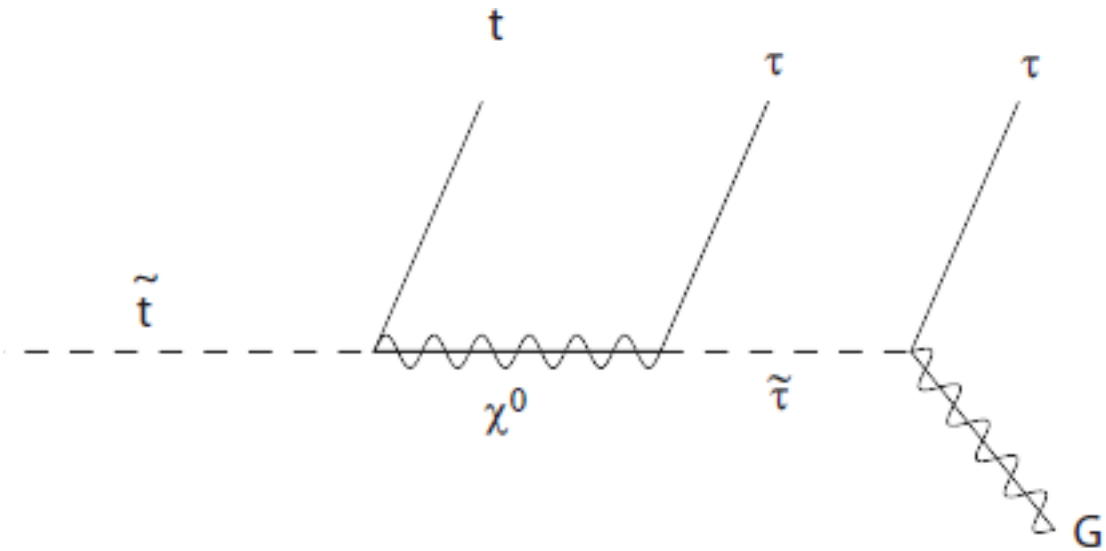
neutral gaugino mass		chargino mass		squark mass		slepton mass	
m_g	6000			m_{u_l}	903	m_{e_l}	463
$m_{\chi_4^0}$	6001	$m_{\chi_2^+}$	6001	m_{d_l}	903	m_{e_r}	203
$m_{\chi_3^0}$	5000						
$m_{\chi_2^0}$	500.4	$m_{\chi_1^+}$	499.5				
$m_{\chi_1^0}$	498.9			m_{u_r}	782	m_{τ_1}	199
				m_{d_r}	784		

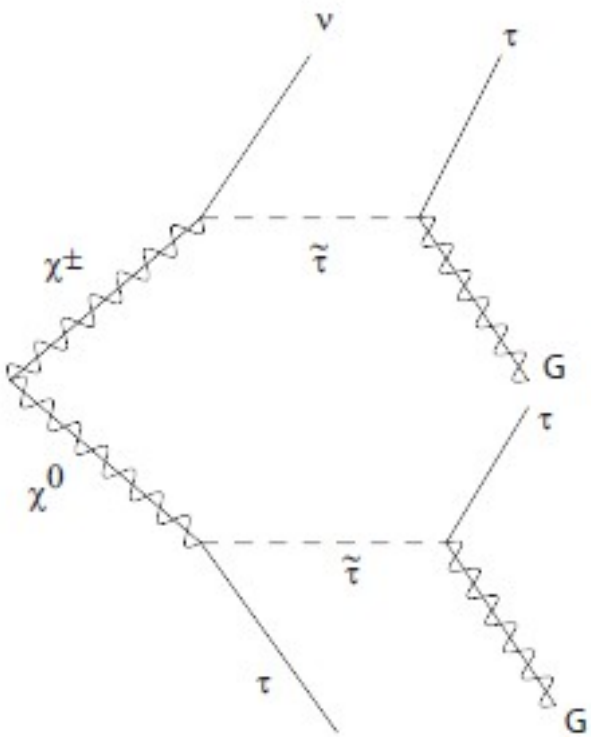
particle	decay	b.f.	particle	decay	b.f.
$\widetilde{u}_l$	$\chi_1^{\pm}$d	.78	$\widetilde{t}_2$	$\chi_1^{\pm}$ b	.38
-	χ_1^0 u	.20	-	χ_1^0 t	.57
-			$\widetilde{t}_1$	χ_1^0 t	.72
$\widetilde{u}_r$	χ_1^0 u	.96	-	$\chi_1^{\pm}$ b	.27
$\widetilde{d}_l$	$\chi_1^{\pm}$u	.49	$\widetilde{b}_2$	$\chi_1^{\pm}$ t	.99
-	χ_1^0 d	.49	$\widetilde{b}_1$	χ_1^0 b	.45
$\widetilde{d}_r$	χ_1^0 d	.96	-	χ_2^0	.41

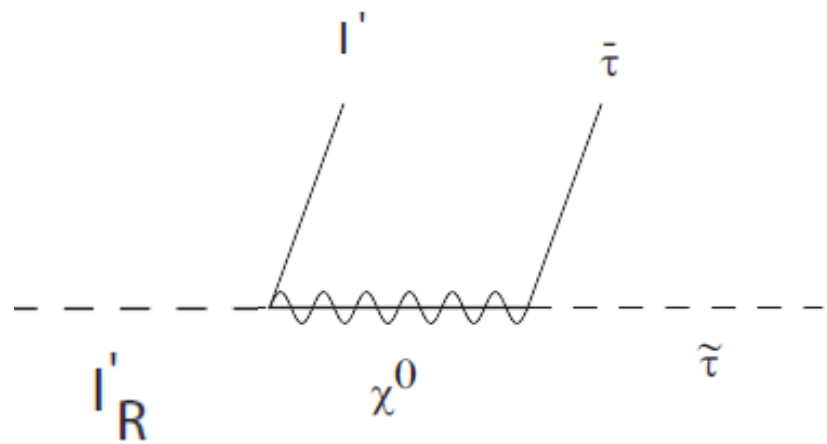
Anti-split SUSY

$\chi_1^{\pm}$	$\nu_\tau\ \widetilde{\tau^{\pm}}$	.94	$\widetilde{\ell}_L$	$\ell\ \ell'^{\mp}\ \widetilde{\ell^{\pm}}'_R$	.632
χ_1^0	$\tau^{\mp}\ \widetilde{\tau^{\pm}}$	.79	-	$\ell\ \tau^{\mp}\ \widetilde{\tau}_R^{\pm}$	.316
-	$\ell^{\mp}\widetilde{\ell^{\pm}}$	.17	$\widetilde{\ell}_R$	$\ell\ \tau^{\mp}\ \widetilde{\tau}_R^{\pm}$	1
χ_2^0	$\tau^{\mp}\ \widetilde{\tau^{\pm}}$	.96	$\widetilde{\tau_R}$	$\tau\ \widetilde{G}$	1

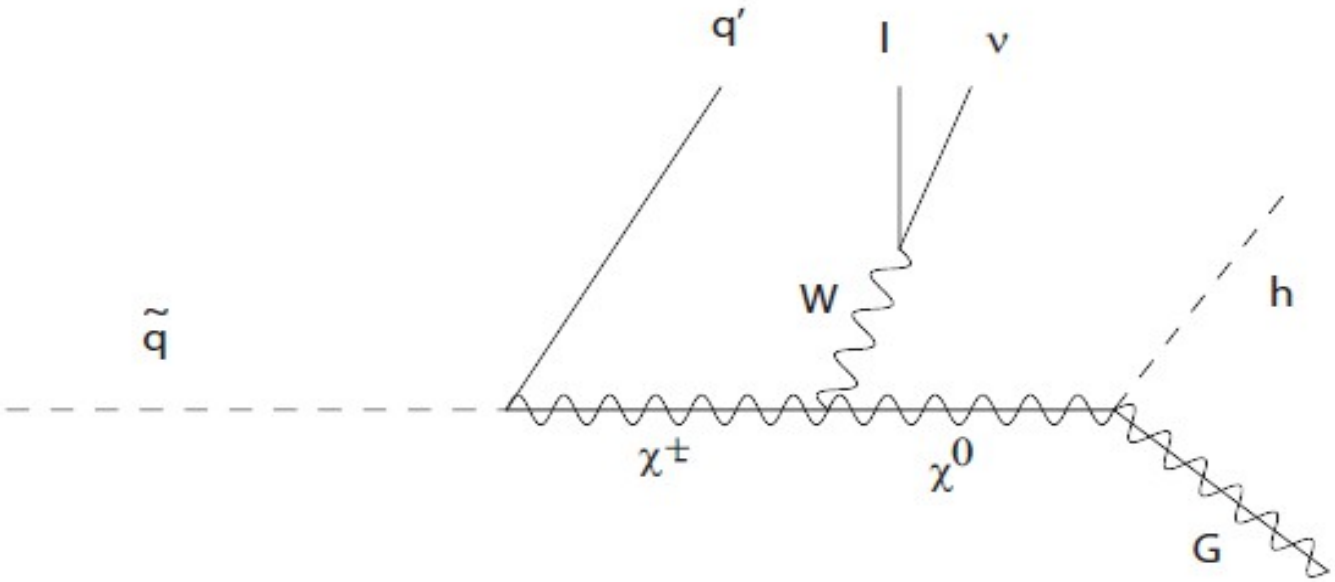
Stau NLSP scenario


t
τ
τ
t̃
χ0
τ̃
G


ν
τ
χ±
τ̃
G
τ
χ0
τ̃
τ
G


l'
τ̄
l'R
χ0
τ̃

Higgsino NLSP



$\chi_0 \to Z/h$ Where tanb and the mu term will determine the ratio of final states

$$\Gamma_Z/\Gamma_H = \frac{(N_{13}c\beta - N_{14}s\beta)^2}{(N_{13}c\beta + N_{14}s\beta)^2}\frac{(1 - m_Z^2/m_{\chi_0}^2)^4}{(1 - m_h^2/m_{\chi_0}^2)^4}$$

Smoking Gun SUSY processes

process	$\widetilde{\nu} NLSP$	Higgsino $NLSP$	$\widetilde{\tau} NLSP$
$\widetilde{q}\widetilde{q}$	$6j + 2\tau + \not{E}_T$ $4j + 2\tau + \ell + \not{E}_T$	$6j + 4b + \not{E}_T$ $4j + \ell + 4b + \not{E}_T$	$2j + 4\tau + \not{E}_T$ $2j + 2\tau + \not{E}_T$
$\chi_1^+\chi_1^-$	$2\tau + \not{E}_T$	$4j + 4b + \not{E}_T$	$2\tau + \not{E}_T$
$\chi^0\chi^0$	$2\tau + 4j + \not{E}_T$ $2\tau + 2j + \ell + \not{E}_T$	$4b + \not{E}_T$	$4\tau + \not{E}_T$
$\widetilde{\ell}\widetilde{\ell}$	$4j + \not{E}_T$ $\ell'\ell'' + \not{E}_T$	$2\ell + 4b + \not{E}_T$	$2\ell + 2\tau + \not{E}_T$ $6\ell + 4\tau + \not{E}_T$

Conclusions

LHC continues to take data constraining minimal models , SUSY is constrained but not down for the count

I'll be back when the day is new

We need to think harder about how to make SUSY discoverable and find new limits

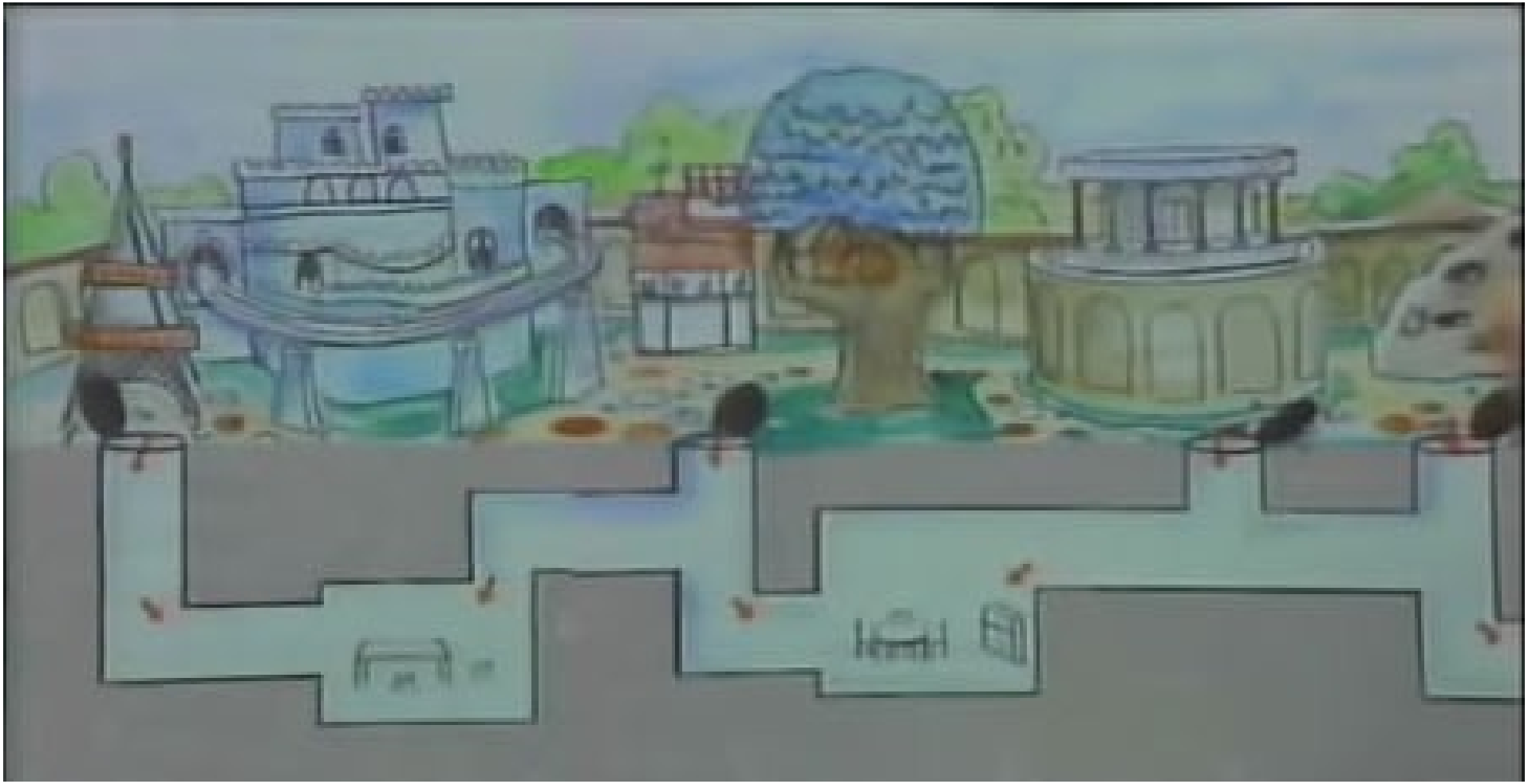
I'll have more ideas for you

Optimizing familiar scenarios for HL-LHC, and pushing into territory of new signatures: Long lived Particles(Split and Antisplit SUSY), Compressed scenarios(Staelth SUSY), Novel Decay chains and LSP possibilities(General Gauge Mediation, new Mediation Mechanisms), and all combinations thereof

You'll have things You want to talk about

See you next PHENO with more physics

I will too



TeVPA 2017

tevpa2017.osu.edu

- August 7–11, Columbus, OH
- Registration and abstract submission are open
- Pre-meeting mini-workshops on Sunday, August 7