Supersymmetry at a 100 TeV Collider

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work done with K. Bozek, C. Pongitivanichkul, K. Sakurai

Thank you

To China and everyone participating in these studies for all your efforts

Very much appreciated by the community and extremely important for our understanding of physics

Motivating Supersymmetry at 10's to 100's of TeV

- There is substantial motivation for such higher scale supersymmetry:
- The mass of the Higgs boson suggests top squarks with $m_{\tilde{t}} \sim O(10)$TeV
- Flavour constraints are ameliorated
- The moduli problem requires $m_{3/2} \sim O(10)$TeV which naturally gives $m_{3/2} \sim m_{\tilde{q}}$
- The latter is presumably generic in string/M theory (BSA, G. Kane, P. Kumar)
- Anomaly mediation
- Split susy
- **We NEED to know what is going on above the TeV scale**

Motivating a 100 TeV Hadron Collider

- Asides from these physics arguments, there is another point
- With the Higgs there was a "win-win" argument
- But this was NOT the case for the SPS
- Here though, the W-boson was discovered
- This led on to the discovery of the Higgs
- We are in a somewhat similar situation now (possibly with Higgs playing the role the W-boson played in the late 70's/early 80's)

Overview:

- Here we focus on 100 TeV pp-colliders with 3 ab^{-1} of total luminosity
- Will summarise a few previous results on gluino, squark and neutralinos at Future Colliders
- Will then describe a forthcoming stud (BSA with K. Bozek, C. Pongkitivanichkul, K. Sakurai) on neutralinos/charginos
- We study the 2nd lightest neutralino/chargino decaying to a W, Z or h plus a lighter chargino/neutralino in Trilepton plus MET final state
- Conclude, including comments on detector design for 100 TeV collisions

Standarised background samples for 100 TeV (1308.1636, 1309.1057 Snowmass)

- For more realistic studies, we need to include detector response (but rather fast and general).
- Delphes for fast detector simulation [1307.6346]
- SNOWMASS comunity proposed the potential properties of the 100 TeV detector and prepared SM-background samples that should be robust up to $\mathcal{L} = 3000\ fb^{-1}$.
- Different pile-up scenarios considered.

Standarised background samples for 100 TeV, Snowmass

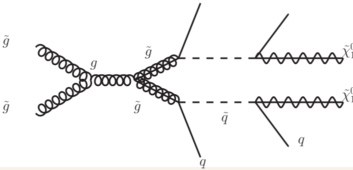
- Background channels relevant for various different analysis.

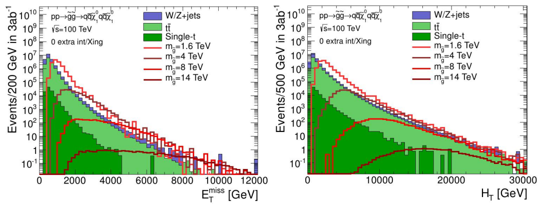
Dataset Name	Main Processes	Final States	Order
Dominant Backgrounds			
B-4p, Bj-4p[a]	vector boson + jets	$V + nJ$	$\mathcal{O}(\alpha_s^n \alpha_w)$
BB-4p	divector + jets	$VV + nJ$	$\mathcal{O}(\alpha_s^n \alpha_w^2)$
TT-4p	top pair + jets	$TT + nJ$	$\mathcal{O}(\alpha_s^{2+n})$
TB-4p	top pair off-shell $T^* \to Wj$ + jets	$TV + nJ$	$\mathcal{O}(\alpha_s^{n+1} \alpha_w)$
TJ-4p	single top (s and t-channel) + jets	$T + nJ$	$\mathcal{O}(\alpha_s^{n-1} \alpha_w^2)$
LL-4p	off-shell $V^* \to LL$ + jets	$LL + nJ$ $[m_{ll} > 20$ GeV$]$	$\mathcal{O}(\alpha_s^n \alpha_w^2)$
Subdominant Backgrounds			
TTB-4p	top pair + boson	$(TTV + nJ), (TTH + nJ)$	$\mathcal{O}(\alpha_s^{2+n} \alpha_w)$
BLL-4p	off-shell divector $V^* \to LL$ + jets	$VLL + nJ$ $[m_{ll} > 20$ GeV$]$	$\mathcal{O}(\alpha_s^n \alpha_w^3)$
BBB-4p	tri-vector + jets, Higgs associated + jets	$(VVV + nJ), (VH + nj)$	$\mathcal{O}(\alpha_s^n \alpha_w^3)$
H-4p	gluon fusion + jets	$H + nJ$	$\mathcal{O}(\alpha_s^n \alpha_h)$
BJJ-vbf-4p	vector boson fusion + jets	$(V + nJ), (H + nJ)$ $[n \geq 2]$	$\mathcal{O}(\alpha_s^{n-2} \alpha_w^3)$

SUSY Simplified Models at Proton Colliders (1311.6480 T. Cohen, T. Golling, M. Hance, A. Henrichs, K. Howe, J. Loyal, S. Padhi, J. Wacker)

Gluino-neutralino model.

- Only 2 accesible BSM particles: $\tilde{g}, \tilde{\chi}_1^0$,
- Signature: jets + missing E_T,
- Background:
  - W/Z+jets
  - $t\bar{t}$
  - single-t
  - VBF W/Z





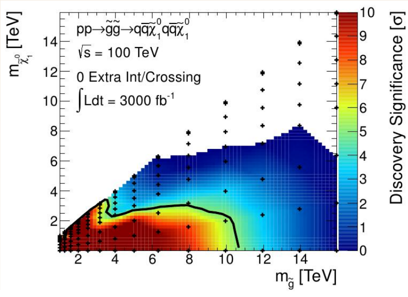
SUSY Simplified Models at Proton Colliders (1311.6480)

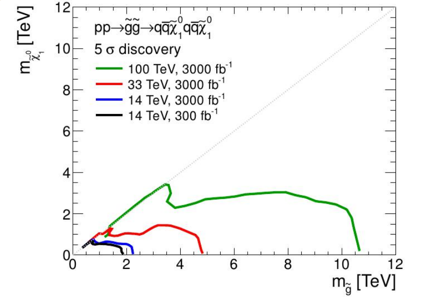
Gluino-neutralino model.

Cut	V+jets	$t\bar{t}$	Total BG	$m_{\tilde{g}}$ [GeV] 5012	9944	13944
Preselection	1.64×10^9	3.33×10^9	4.97×10^9	1.12×10^5	876	43.4
$E_T^{\text{miss}}/\sqrt{H_T} > 15\ \text{GeV}^{1/2}$	3.59×10^7	3.31×10^7	6.90×10^7	7.99×10^4	740	38.8
$p_T^{\text{leading}} < 0.4 \times H_T$	1.19×10^7	1.25×10^7	2.44×10^7	4.87×10^4	443	22.7
$E_T^{\text{miss}} > 5150$ GeV, $H_T > 9550$ GeV	21.6	33.1	54.8	216	91.6	10.7
$E_T^{\text{miss}} > 5530$ GeV, $H_T > 9750$ GeV	12	18.9	30.9	136	67.4	9.2
$E_T^{\text{miss}} > 6150$ GeV, $H_T > 11700$ GeV	4.1	6.3	10.4	33.6	29.6	6.8

Definitions of SRs.

SUSY Simplified Models at Proton Colliders (1311.6480)





SUSY Simplified Models Summary (1311.6480)

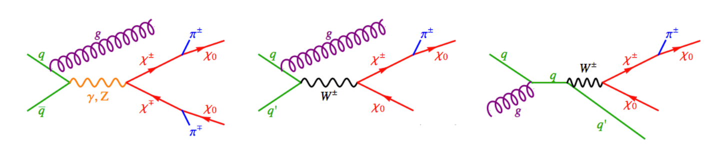
Simplified Model	14 TeV 300 fb^{-1}	14 TeV 3000 fb^{-1}	33 TeV	100 TeV
$\tilde{g}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{\chi}_1^0} \simeq 0$	1.9 TeV [2.3 TeV]	2.2 TeV [2.7 TeV]	5.0 TeV [5.8 TeV]	11 TeV [13.5 TeV]
$\tilde{g}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{g}} \simeq m_{\tilde{\chi}_1^0}$	0.75 TeV [0.9 TeV]	0.9 TeV [1.0 TeV]	1.5 TeV [1.8 TeV]	4.6 TeV [5.5 TeV]
$\tilde{q}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{\chi}_1^0} \simeq 0$	0.80 TeV [1.5 TeV]	0.9 TeV [1.7 TeV]	1.4 TeV [3.4 TeV]	2.4 TeV [8.0 TeV]
$\tilde{q}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{q}} \simeq m_{\tilde{\chi}_1^0}$	0.45 TeV [0.65 TeV]	0.45 TeV [0.70 TeV]	0.80 TeV [1.3 TeV]	3.0 TeV [3.9 TeV]
$\tilde{g}$ - $\tilde{q}$- $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{g}} \simeq m_{\tilde{q}}$ and $m_{\tilde{\chi}_1^0} \simeq 0$	2.7 TeV [2.8 TeV]	3.0 TeV [3.2 TeV]	6.6 TeV [6.8 TeV]	15.5 TeV [16 TeV]
$\tilde{g}$ - $\tilde{\chi}_1^0$ heavy flavor decays $m_{\tilde{\chi}_1^0} \simeq 0$	1.6 TeV [1.9 TeV]	2.0 TeV [2.4 TeV]	3.4 TeV [3.9 TeV]	6.3 TeV [8.8 TeV]

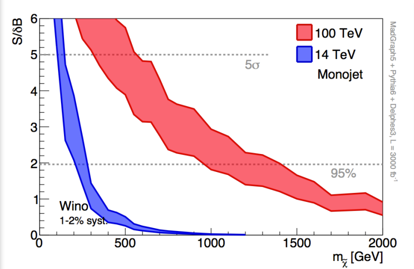
Electroweak-inos in 100 TeV pp-collisions

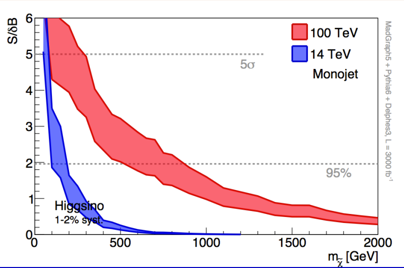
- Here we consider $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow W^{\pm}\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$ with the bosons decayig leptonically
- For $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow W^{\pm}\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$ simplified model with $m_{\tilde{\chi}_1^{\pm}} = m_{\tilde{\chi}_2^0}$ and $m_{\tilde{\chi}_1^0} = 0$ GeV, ATLAS and CMS limits are currently around 400 GeV
- 5σ reach at 14 TeV estimated to be 550 GeV and 800 GeV at 300 fb^{-1} and 3000fb^{-1} (ATLAS).
- **The LHC has a very limited reach :-((**
- We assume the squarks, sleptons and B-ino are decoupled for simplicity.
-

Previous studies: Monojet search

- pp $\rightarrow \chi\chi$ + jet [M. Low, L.T. Wang 2014; M. Cirelli, F. Sala, M. Taoso 2014]

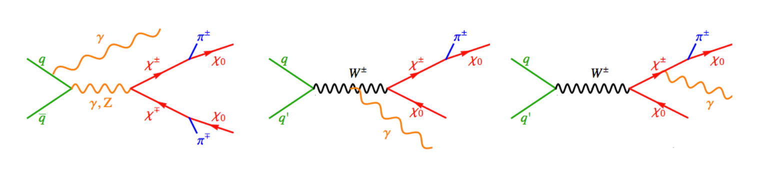


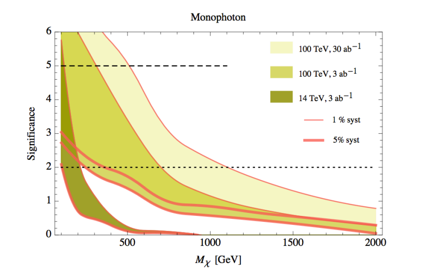




Monophoton search

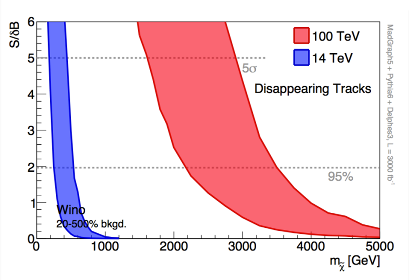
- pp $\rightarrow \chi\chi$ + photon [M. Cirelli, F. Sala, M. Taoso 2014]

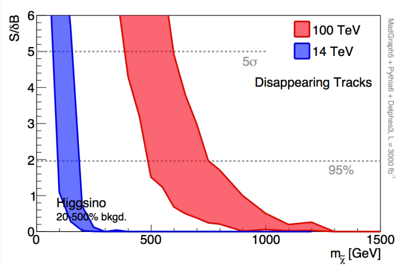




Previous studies: Disappearing track

- chargino-neutralino are degenerated at tree level $\rightarrow$ disappearing track [M. Low, L.T. Wang 2014; M. Cirelli, F. Sala, M. Taoso 2014]





Simulation and Analysis Framework

- Signal Event Generation: Madgraph 5
- Decays: BRIDGE
- Shower/Hadronisation: PYTHIA
- Detector sim: Delphes3, Snowmass tune
- Background Samples: Snowmass

Analysis Validation

We first reproduced existing results on strong susy production We then compared to the ATLAS 8 TeV trileptons plus MET to help validate:

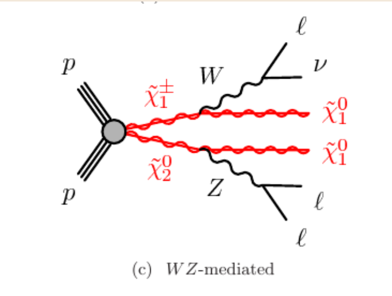
Our analysis						
$(m_{\chi_1^0}, m_{\chi_1^\pm})$	bins	events	$\not{E}_T$	m_T	3 leptons Z veto	efficiency
(100, 175) GeV	9	27405	23	11	8	0.029 %
	10	27405	23	11	11	0.040 %
	11	27405	18	12	12	0.044 %
	12	27405	18	5.5	5.5	0.020 %
(50, 350) GeV	13	1502.2	1.6	0.8	0.8	0.053 %
	14	1502.2	12.5	3.7	3.7	0.246 %
	15	1502.2	4.7	2.3	2.3	0.153 %
	16	1502.2	9.3	7.3	7.3	0.486 %
ATLAS analysis						
$(m_{\chi_1^0}, m_{\chi_1^\pm})$	bins	events	$\not{E}_T$	m_T	3 leptons Z veto	efficiency
(100, 175) GeV	9	27405	20	13	10	0.036 %
	10	27405	20	7	13	0.047 %
	11	27405	19	15	15	0.055 %
	12	27405	19	4	4	0.015 %
(50, 350) GeV	13	1502.2	1.1	0.6	0.6	0.040 %
	14	1502.2	8	2.4	2.4	0.160 %
	15	1502.2	2.9	1.6	1.6	0.107 %
	16	1502.2	7	5	5	0.333 %

Table: Validation of analysis code: comparing signal events with ATLAS study

Analysis Validation

We also cross-checked some of the snowmass background samples against our own Pythia event generation and showering plus Delphes simulation

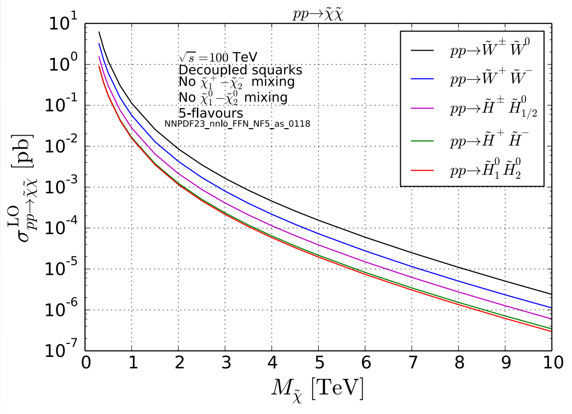
Production/Decay



(a)

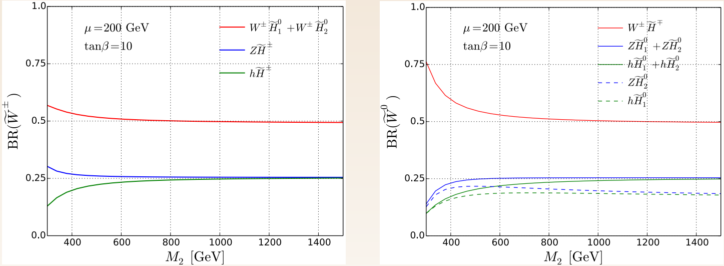
Figure: Chargino/Neutralino or Chargino Pair Production are Considered

Kinematics at 100 TeV



The leading order cross sections for the W-ino and Higgsino pair productions at a 100 TeV proton-proton collider with decoupled squarks and sleptons.

Branching Ratios



(a) (b)

Figure: **(a)** the branching ratio of $\widetilde{W}^{\pm}$. **(b)** the branching ratio of $\widetilde{W}^{0}$.

Kinematics at 100 TeV

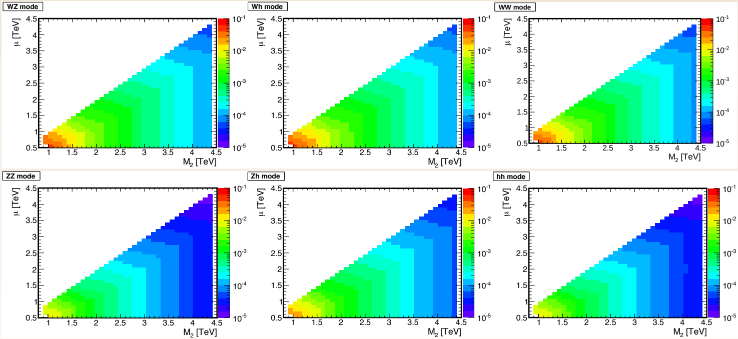
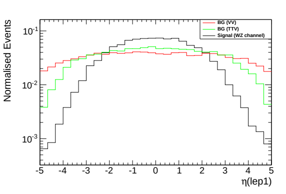
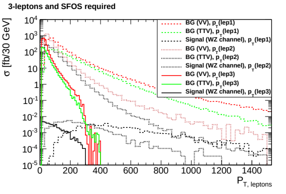


Figure: The cross sections of the 6-modes, clockwise $\chi'\chi' \to XY\chi\chi$ with $XY = WZ, Wh, WW, ZZ, Zh$ and hh, as functions of M_2 and μ. W-inos and Higgsinos are considered, and the squarks are decoupled.

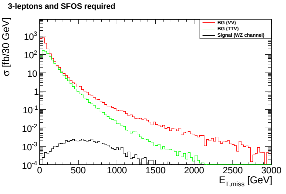
Requiring 3 leptons and OSSF cut



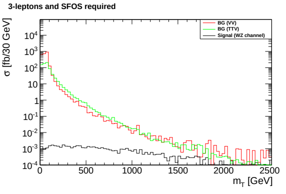
(a)



(b)

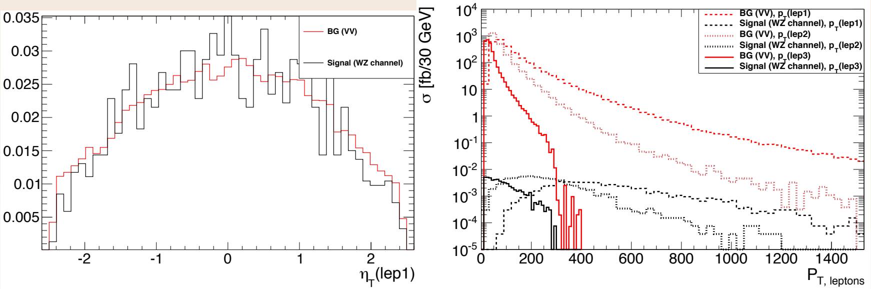


(c)

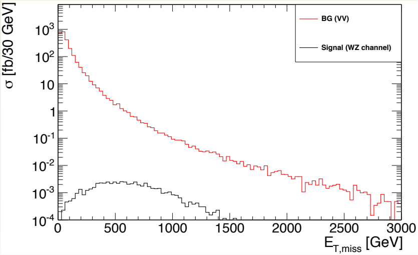


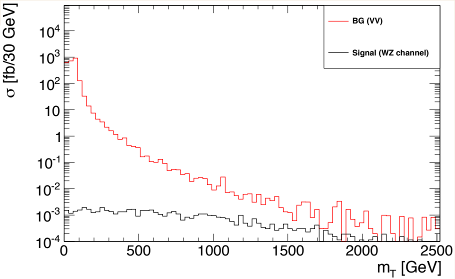
(d)

Kinematics at 100 TeV after Detector Reco



Kinematics at 100 TeV





3 Lepton pT, ET-miss and mT cuts

SRCuts	lepton P_T [GeV]	E_T^{miss} [GeV]	m_T [GeV]
16	ATLAS trigger	> 135	> 110
26	$p_{T1} > 150$ $p_{T2} > 100$ $p_{T3} > 50$	> 200	> 200
27	$p_{T1} > 250$ $p_{T2} > 150$ $p_{T3} > 50$	> 350	> 300
28	$p_{T1} > 350$ $p_{T2} > 150$ $p_{T3} > 75$	> 400	> 350
29	$p_{T1} > 400$ $p_{T2} > 200$ $p_{T3} > 75$	> 600	> 500

Table: Five signal regions used in the analysis.

Background Cross-sections in Signal Regions

signal region	process	$\sigma_{\rm eff}^{\rm NLO}$ [fb]	$\sigma_{\rm total\ eff}^{\rm NLO}$ [fb]
SR16	$t\bar{t}+V$	15.8518	29.1356
	VV	11.1193	
	VVV	2.0588	
	t+V	0.1057	
SR26	$t\bar{t}+V$	1.0874	2.3136
	VV	1.0037	
	VVV	0.2178	
	t+V	0.0047	
SR27	$t\bar{t}+V$	0.1187	0.2702
	VV	0.1060	
	VVV	0.0442	
	t+V	0.0013	
SR28	$t\bar{t}+V$	0.0297	0.0868
	VV	0.0409	
	VVV	0.0160	
	t+V	0.0002	
SR29	$t\bar{t}+V$	0.0045	0.0148
	VV	0.0055	
	VVV	0.0047	
	t+V	0.0001	

Table: SNOWMASS SM background cross-sections in Signal Regions. Note that the relative contributions of different background components changed **dramatically** from 8 TeV to 100 TeV

Backgrounds at 8 TeV

ATLAS 8 TeV

Process	Nr of events
WZ	$3.9^{+1.6}_{-1.4}$
WWW/ZWW	0.33 ± 0.33
ZZ	$0.12^{+0.08}_{-0.07}$
$t\bar{t}V + tZ$	$0.08^{+0.1}_{-00.08}$
$W/Z + jets$	$0.14^{+0.25}_{-0.14}$

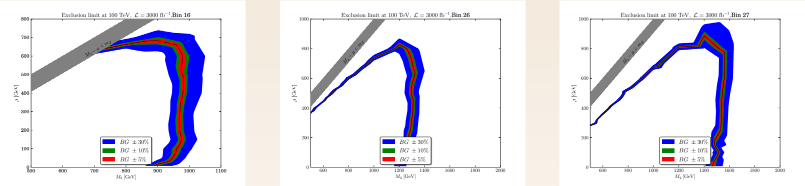
At 100 TeV tt+V, VV and VVV all comparable – see previous slide

Signal Cross-Sections in Signal Regions

Model (M_2, μ) [GeV]	$\sigma^{\rm LO}_{\rm total}$ [fb]	$\sigma^{\rm LO}_{\rm eff}$ [fb]				
		bin 16	bin 26	bin 27	bin 28	bin 29
(500, 200)	1585.9	1.3307	0.2713	0.0306	0.0069	0.0012
(800, 200)	350.3	0.3848	0.1739	0.0777	0.0308	0.0040
(1100, 200)	116.3	0.1179	0.0683	0.0428	0.0230	0.0103
(1400, 200)	48.5	0.0441	0.0272	0.0206	0.0126	0.0073
(1700, 200)	23.4	0.0187	0.0122	0.0096	0.0063	0.0043

Table: Effective Cross sections of signal sample for selected model points in the signal regions.

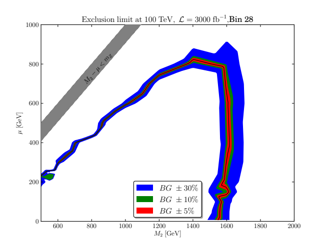
Results



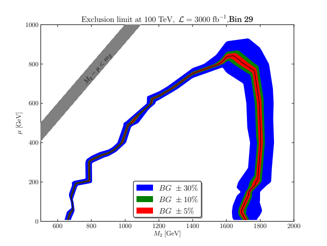
(a) (b) (c)

Figure: Exclusion limits for individual signal regions.

Results



(a)



(b)

Figure: Exclusion limits for individual signal regions. We include 10% and 30% uncertainty bands. One could exclude W-inos up to 1.7 TeV!

Conclusions

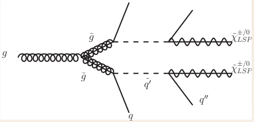
- A lot of studies on supersymmetry already undertaken, much more to be done
- High energy pp collisions from 50 to 100 TeV could significantly improve our understanding of supersymmetry
- Crucial for understanding electroweak symmetry breaking and potential dark matter candidates
- In our study we should a significant improvement in the susy WIMP sector with a simple approach
- One can probably go much further with a more detailed treatment, including many other channels, other variables
- Also important to consider final states without substantial missing energy e.g. RPV
- **Forward Tracking and Calorimetry may prove crucial at these energies**

Backup

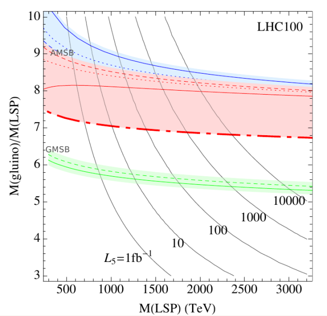
Gauginos in split SUSY through gluino pair production (1312.1802)

- Masses of scalars are $m_{\tilde{g}} < m_{scalars} < m_{3/2}$,
- Probing LSP through gluino pair production and hadronic final state,
- Signature: jets + missing E_T,
- Core of the analysis based on Madgraph+Pythia parton level events and cuts on

$$M_{eff} = \sum_{jets} p_T + E_T^{miss}$$



Results



- Luminosity contours required for 5σ discovery,
- Blue and red contours – AMSB predictions (Wino-LSP),
- Green contour – mGMSB predictions (Higgsino-LSP),
- Discovery reach up to 2.2 TeV for Wino-LSP
- Discovery reach up to 2.8 TeV for Bino-LSP

Standarised background samples for 100 TeV (1308.1636, 1309.1057)

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Standarised background samples for 100 TeV

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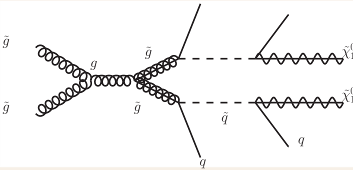
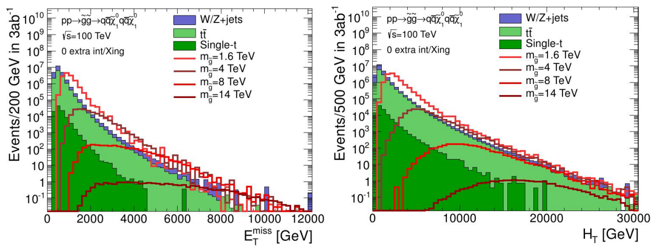
TB-4p	top pair off-shell $T^* \to Wj$ + jets	$TV + nJ$	$\mathcal{O}(\alpha_s^{n+1} \alpha_w)$
TJ-4p	single top (s and t-channel) + jets	$T + nJ$	$\mathcal{O}(\alpha_s^{n-1} \alpha_w^2)$
LL-4p	off-shell $V^* \to LL$ + jets	$LL + nJ$ [$m_{ll} > 20$ GeV]	$\mathcal{O}(\alpha_s^n \alpha_w^2)$
Subdominant Backgrounds			
TTB-4p	top pair + boson	$(TTV + nJ), (TTH + nJ)$	$\mathcal{O}(\alpha_s^{2+n} \alpha_w)$
BLL-4p	off-shell divector $V^* \to LL$ + jets	$VLL + nJ$ [$m_{ll} > 20$ GeV]	$\mathcal{O}(\alpha_s^n \alpha_w^3)$
BBB-4p	tri-vector + jets, Higgs associated + jets	$(VVV + nJ), (VH + nj)$	$\mathcal{O}(\alpha_s^n \alpha_w^3)$
H-4p	gluon fusion + jets	$H + nJ$	$\mathcal{O}(\alpha_s^n \alpha_h)$
BJJ-vbf-4p	vector boson fusion + jets	$(V + nJ), (H + nJ)$ [$n \geq 2$]	$\mathcal{O}(\alpha_s^{n-2} \alpha_w^3)$

SUSY Simplified Models at Proton Colliders (1311.6480)

Gluino-neutralino model.

- Only 2 accesible BSM particles: $\tilde{g}, \tilde{\chi}_1^0$,
- Signature: jets + missing E_T,
- Background:
  W/Z+jets
  $t\bar{t}$
  single-t
  VBF W/Z





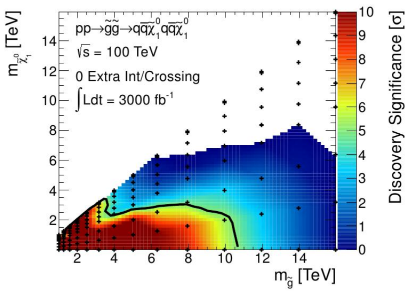
SUSY Simplified Models at Proton Colliders (1311.6480)

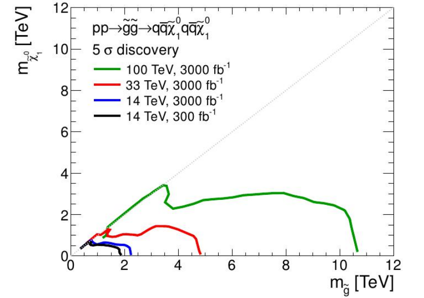
Gluino-neutralino model.

Cut	V+jets	$t\bar{t}$	Total BG	$m_{\tilde{g}}$ [GeV] 5012	9944	13944
Preselection	1.64×10^9	3.33×10^9	4.97×10^9	1.12×10^5	876	43.4
$E_T^{\text{miss}}/\sqrt{H_T} > 15\ \text{GeV}^{1/2}$	3.59×10^7	3.31×10^7	6.90×10^7	7.99×10^4	740	38.8
$p_T^{\text{leading}} < 0.4 \times H_T$	1.19×10^7	1.25×10^7	2.44×10^7	4.87×10^4	443	22.7
$E_T^{\text{miss}} > 5150$ GeV, $H_T > 9550$ GeV	21.6	33.1	54.8	216	91.6	10.7
$E_T^{\text{miss}} > 5530$ GeV, $H_T > 9750$ GeV	12	18.9	30.9	136	67.4	9.2
$E_T^{\text{miss}} > 6150$ GeV, $H_T > 11700$ GeV	4.1	6.3	10.4	33.6	29.6	6.8

Definitions of SRs.

SUSY Simplified Models at Proton Colliders (1311.6480)

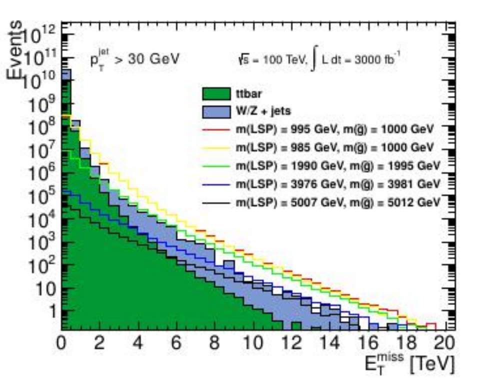




SUSY Simplified Models at Proton Colliders (1311.6480)

Compressed Gluino-neutralino model.

- Background:
  W/Z+jets
  $t\bar{t}$



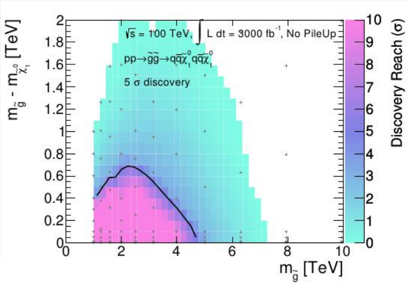
SUSY Simplified Models at Proton Colliders (1311.6480)

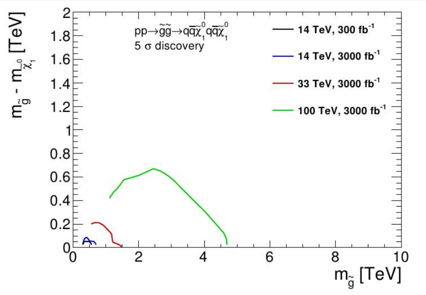
Compressed gluino-neutralino model.

Cut	V+jets	$t\bar{t}$	Total BG	$(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ [GeV] (1995, 1990)	(2512, 2507)	(5012, 5007)
Preselection	1.7×10^{10}	7.0×10^{9}	2.4×10^{10}	1.3×10^{7}	4.1×10^{6}	7.9×10^{4}
$p_T^{\text{leadjet}} > 110$ GeV, $\lvert\eta^{\text{leadjet}}\rvert < 2.4$	1.2×10^{10}	6.1×10^{9}	1.9×10^{10}	1.3×10^{7}	4.1×10^{6}	7.9×10^{4}
$E_T^{\text{miss}} > 3$ TeV	1.3×10^{5}	2.0×10^{4}	1.5×10^{5}	1.9×10^{5}	9.4×10^{4}	4.8×10^{3}
$E_T^{\text{miss}} > 6$ TeV	3.6×10^{3}	229	3.8×10^{3}	8.0×10^{3}	5.1×10^{3}	509
$E_T^{\text{miss}} > 9$ TeV	100	9	109	612	410	67

Definitions of SRs.

SUSY Simplified Models at Proton Colliders (1311.6480)



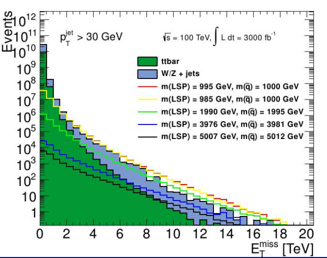


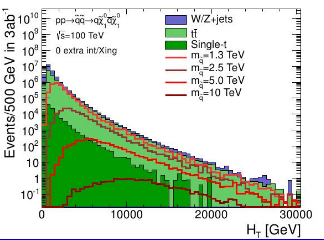
SUSY Simplified Models at Proton Colliders (1311.6480)

Squark-neutralino model.

- The fist and second generation squarks+ neutralino: $\tilde{q}, \tilde{\chi}_1^0$,
- Signature: jets + missing E_T,
- Background:
  W/Z+jets
  $t\bar{t}$
  single-t
  VBF W/Z

BSM particles	production	decays
$\tilde{q},\ \tilde{\chi}_1^0$	$p\,p \to \tilde{q}\,\tilde{q}^*$	$\tilde{q} \to q\,\tilde{\chi}_1^0$





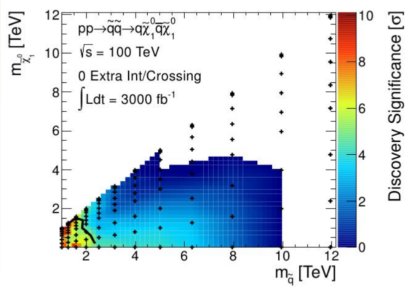
SUSY Simplified Models at Proton Colliders (1311.6480)

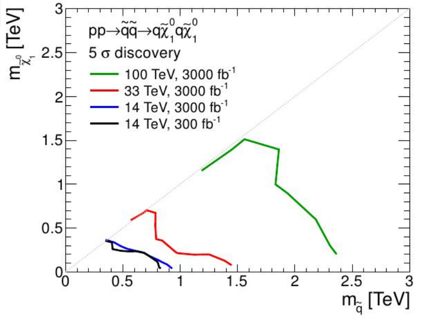
Squark-neutralino model.

Cut	V+jets	$t\bar{t}$	Total BG	$m_{\tilde{q}}$ [GeV] 3162	5012	7944
Preselection	1.64×10^9	3.33×10^9	4.97×10^9	2.01×10^5	1.44×10^4	668
$E_T^{\text{miss}}/\sqrt{H_T} > 15$ GeV$^{1/2}$	3.59×10^7	3.31×10^7	6.90×10^7	1.62×10^5	1.26×10^4	614
$p_T^{\text{leading}} < 0.4 \times H_T$	1.19×10^7	1.25×10^7	2.44×10^7	4.14×10^4	2.63×10^3	96.9
$E_T^{\text{miss}} > 5550$ GeV, $H_T > 900$ GeV	24	21.2	45.1	73.3	60.1	19.9
$E_T^{\text{miss}} > 4900$ GeV, $H_T > 5450$ GeV	61.2	53.3	114	119	143	29.5
$E_T^{\text{miss}} > 6150$ GeV, $H_T > 8200$ GeV	9.2	8.4	17.6	11.2	17	11.5

Definitions of SRs.

SUSY Simplified Models at Proton Colliders (1311.6480)

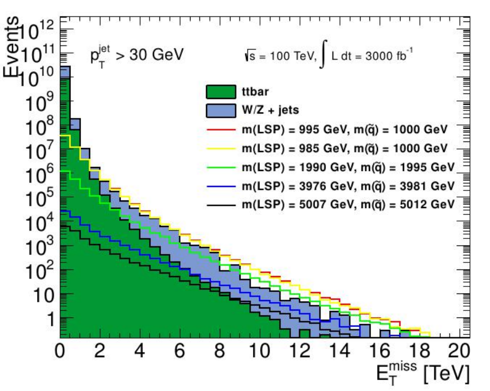




SUSY Simplified Models at Proton Colliders (1311.6480)

Compressed Squark-neutralino model.

- Background:
  W/Z+jets
  $t\bar{t}$



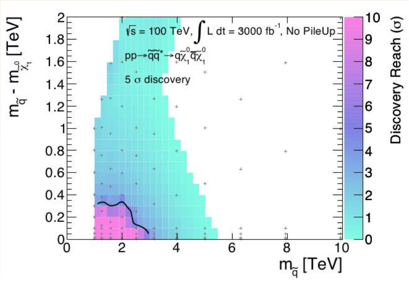
SUSY Simplified Models at Proton Colliders (1311.6480)

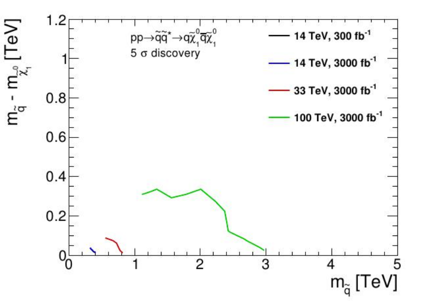
Compressed squark-neutralino model.

Cut	V+jets	$t\bar{t}$	Total BG	$(m_{\tilde{q}}, m_{\tilde{\chi}_1^0})$ [GeV] (1995, 1990)	(2512, 2507)	(5012, 5007)
Preselection	1.7×10^{10}	7.0×10^{9}	2.4×10^{10}	2.0×10^{6}	6.4×10^{5}	1.4×10^{4}
$p_T^{\text{leadjet}} > 110$ GeV, $\|\eta^{\text{leadjet}}\| < 2.4$	1.2×10^{10}	6.1×10^{9}	1.9×10^{10}	2.0×10^{6}	6.4×10^{5}	1.4×10^{4}
$E_T^{\text{miss}} > 3$ TeV	1.3×10^{5}	2.0×10^{4}	1.5×10^{5}	4.1×10^{4}	1.9×10^{4}	935
$E_T^{\text{miss}} > 6$ TeV	3.6×10^{3}	229	3.8×10^{3}	2.3×10^{3}	$1. \times 10^{3}$	116
$E_T^{\text{miss}} > 9$ TeV	100	9	109	206	130	17

Definitions of SRs.

SUSY Simplified Models at Proton Colliders (1311.6480)



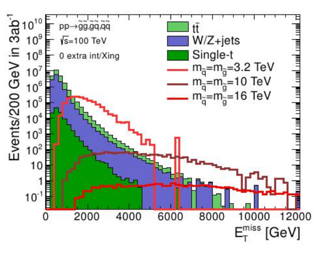


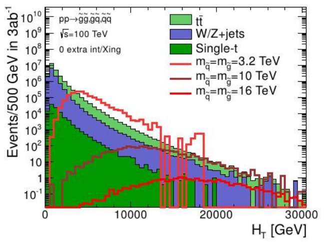
SUSY Simplified Models at Proton Colliders (1311.6480)

BSM particles	production	decay
$\tilde{g},\, \tilde{q},\, \tilde{\chi}_1^0$	$pp \to \tilde{g}\,\tilde{g}$ $pp \to \tilde{g}\,\tilde{q}$ $pp \to \tilde{g}\,\tilde{q}^*$ $pp \to \tilde{q}\,\tilde{q}^*$ $pp \to \tilde{q}\,\tilde{q}$	$\tilde{g} \to \begin{cases} \tilde{q}\,\bar{q} & \text{for } m_{\tilde{g}} > m_{\tilde{q}} \\ q\,\bar{q}\,\tilde{\chi}_1^0 & \text{for } m_{\tilde{g}} \simeq m_{\tilde{q}} \\ q\,\bar{q}\,\tilde{\chi}_1^0 & \text{for } m_{\tilde{g}} < m_{\tilde{q}} \end{cases}$ $\tilde{q} \to \begin{cases} q\,\tilde{\chi}_1^0 & \text{for } m_{\tilde{g}} > m_{\tilde{q}} \\ q\,\tilde{\chi}_1^0 & \text{for } m_{\tilde{g}} \simeq m_{\tilde{q}} \\ q\,\tilde{g} & \text{for } m_{\tilde{g}} < m_{\tilde{q}} \end{cases}$

Squark-gluino-neutralino model.

- Signature: jets + missing E_T,
- Background:
  W/Z+jets
  $t\bar{t}$
  single-t
  VBF W/Z





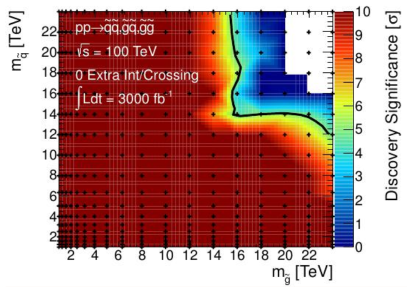
SUSY Simplified Models at Proton Colliders (1311.6480)

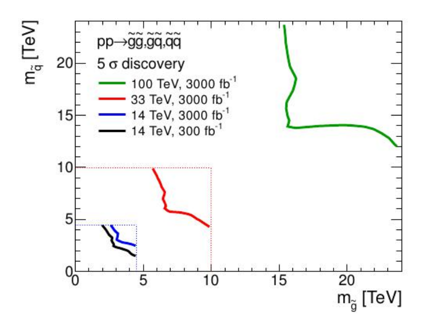
Squark-gluino-neutralino model.

Cut	V+jets	$t\bar{t}$	Total BG	$(m_{\tilde{g}}, m_{\tilde{q}})$ $(8,8)$	[TeV] $(16,16)$
Preselection	1.64×10^9	3.33×10^9	4.97×10^9	2.69×10^4	111
$E_T^{\text{miss}}/\sqrt{H_T} > 15\ \text{GeV}^{1/2}$	3.59×10^7	3.31×10^7	6.90×10^7	2.41×10^4	107
$p_T^{\text{leading}} < 0.4 \times H_T$	1.19×10^7	1.25×10^7	2.44×10^7	7.34×10^3	20.5
$E_T^{\text{miss}} > 5700$ GeV, $H_T > 8000$ GeV	13	14.9	27.8	771	12
$E_T^{\text{miss}} > 5800$ GeV, $H_T > 17800$ GeV	0.4	2.5	2.9	41.7	5.3

Definitions of SRs.

SUSY Simplified Models at Proton Colliders (1311.6480)





SUSY Simplified Models at Proton Colliders (1311.6480)

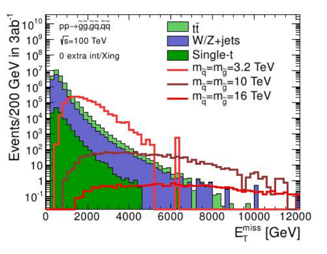
- Asides from these physics arguments, there is another point
- With the Higgs there was a "win-win" argument
- But this was NOT the case for the SPS
- Here though, the W-boson was discovered
- This led on to the discovery of the Higgs
- We are in a somewhat similar situation now (possibly with Higgs playing the role the W-boson played in the late 70's/early 80's)

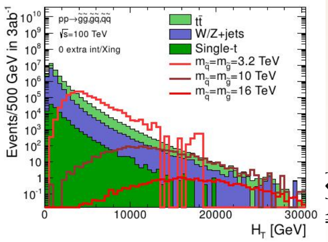
SUSY Simplified Models at Proton Colliders (1311.6480)

Gluino-neutralino with heavy flavour decay

- Signature: Same Sign Di-lepton (SSDL)
- Background:
  t$\bar{t}$
  Wbb

BSM particles	production	decays
$\tilde{g},\ \tilde{\chi}_1^0$	$p\,p \to \tilde{g}\,\tilde{g}$	$\tilde{g} \to t\,\bar{t}\,\tilde{\chi}_1^0$





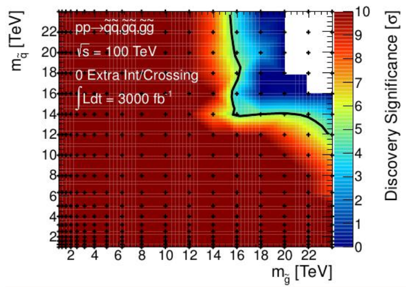
SUSY Simplified Models at Proton Colliders (1311.6480)

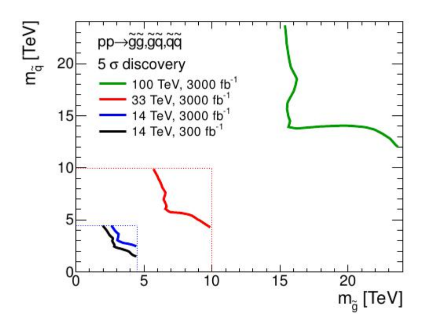
gluino-neutralino model with heavy flavour decay.

Cut	V+jets	$t\bar{t}$	Total BG	$(m_{\tilde{g}}, m_{\tilde{q}})$ (8, 8)	[TeV] (16, 16)
Preselection	1.64×10^9	3.33×10^9	4.97×10^9	2.69×10^4	111
$E_T^{\text{miss}}/\sqrt{H_T} > 15\ \text{GeV}^{1/2}$	3.59×10^7	3.31×10^7	6.90×10^7	2.41×10^4	107
$p_T^{\text{leading}} < 0.4 \times H_T$	1.19×10^7	1.25×10^7	2.44×10^7	7.34×10^3	20.5
$E_T^{\text{miss}} > 5700$ GeV, $H_T > 8000$ GeV	13	14.9	27.8	771	12
$E_T^{\text{miss}} > 5800$ GeV, $H_T > 17800$ GeV	0.4	2.5	2.9	41.7	5.3

Definitions of SRs.

SUSY Simplified Models at Proton Colliders (1311.6480)





SUSY Simplified Models at Proton Colliders (1311.6480)

Simplified Model	14 TeV 300 fb^{-1}	14 TeV 3000 fb^{-1}	33 TeV	100 TeV
$\tilde{g}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{\chi}_1^0} \simeq 0$	1.9 TeV [2.3 TeV]	2.2 TeV [2.7 TeV]	5.0 TeV [5.8 TeV]	11 TeV [13.5 TeV]
$\tilde{g}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{g}} \simeq m_{\tilde{\chi}_1^0}$	0.75 TeV [0.9 TeV]	0.9 TeV [1.0 TeV]	1.5 TeV [1.8 TeV]	4.6 TeV [5.5 TeV]
$\tilde{q}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{\chi}_1^0} \simeq 0$	0.80 TeV [1.5 TeV]	0.9 TeV [1.7 TeV]	1.4 TeV [3.4 TeV]	2.4 TeV [8.0 TeV]
$\tilde{q}$ - $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{q}} \simeq m_{\tilde{\chi}_1^0}$	0.45 TeV [0.65 TeV]	0.45 TeV [0.70 TeV]	0.80 TeV [1.3 TeV]	3.0 TeV [3.9 TeV]
$\tilde{g}$ - $\tilde{q}$- $\tilde{\chi}_1^0$ light flavor decays $m_{\tilde{g}} \simeq m_{\tilde{q}}$ and $m_{\tilde{\chi}_1^0} \simeq 0$	2.7 TeV [2.8 TeV]	3.0 TeV [3.2 TeV]	6.6 TeV [6.8 TeV]	15.5 TeV [16 TeV]
$\tilde{g}$ - $\tilde{\chi}_1^0$ heavy flavor decays $m_{\tilde{\chi}_1^0} \simeq 0$	1.6 TeV [1.9 TeV]	2.0 TeV [2.4 TeV]	3.4 TeV [3.9 TeV]	6.3 TeV [8.8 TeV]