Supersymmetric contributions to Z' decays

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2. Z' production in U(1)$'$ and Sequential Standard Model
3. MSSM features including U(1)$'$
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G.C. and S.Gentile, Nucl.Phys.B886 (2013) 293 and work in progress

Searches for heavy gauge bosons Z' among the main objectives of LHC

GUT-inspired U(1)', Kaluza–Klein gravitons, Sequential Standard Model

LHC analyses focus on SM decays, e.g. high-mass dilepton resonances

CMS: $\mathcal{L}$= 5 fb^{-1} (e^+e^-) and $\mathcal{L}$=5.3 fb^{-1} $(\mu^+\mu^-)$, $\sqrt{s} = 7$ TeV

$m(Z'_{\rm SSM}) > 2.33$ TeV , $m(Z'_{\rm GUT}) > 2.00$ TeV, $m(Z'_{\rm KK}) > 1.81 - 2.14$ TeV

ATLAS: $\mathcal{L}$=5.9 fb^{-1} (e^+e^-) and $\mathcal{L}$=6.1 fb^{-1} $(\mu^+\mu^-)$, $\sqrt{s} = 8$ TeV

$m(Z'_{\rm SSM}) > 2.49$ TeV , $m(Z'_{\rm GUT})$ >2.09-2.24 TeV

In BSM analyses, why not BSM Z' decays, e.g. both SM and MSSM modes

Z' constrains invariant masses; unexplored phase space; monojet events

Lower SM branching ratios with BSM decays $\Rightarrow$ lower Z' mass exclusion limits

T. Gherghetta et al., PRD57 (1998) 3178: pioneering work on Z' decays in the MSSM for $m_{Z'} = 700$ GeV and one point in the parameter space

J. Kang and P. Langacker, PRD71 (2005) 035014: exotic modes vs LHC limits

M. Baumgart et al., JHEP 0711 (2007) 084: $\mathrm{U(1)}'_{\rm B-L}$ and Z' slepton decays

C.-F. Chang et al., JHEP09 (2011) 058: 2 sets of MSSM parameters and $m_{Z'}$=1-2 TeV

U(1)' gauge groups in GUT-inspired models:

$$\mathrm{E}_6 \to \mathrm{SO}(10) \times \mathrm{U}(1)'_\psi \quad , \quad \mathrm{SO}(10) \to \mathrm{SU}(5) \times \mathrm{U}(1)'_\chi$$

$$Z'(\theta) = Z'_\psi \cos\theta - Z'_\chi \sin\theta$$

$$\mathrm{E}_6 \to \mathrm{SM} \times \mathrm{U}(1)_\eta \quad \theta = \arccos\sqrt{5/8} \;\Rightarrow\; Z'_\eta$$

Orthogonal combination to Z'_η: $\theta = \arccos\sqrt{5/8} - \pi/2 \Rightarrow Z'_I$

Secluded model (singlet S): $\theta = \arctan(\sqrt{15}/9) - \pi/2 \Rightarrow Z'_S$

Representations of E_6, $\mathrm{SO}(10)$ and $\mathrm{SU}(5)$:

$$\mathrm{E}_6 \quad : \quad \mathbf{27} = (Q, u^c, e^c, L, d^c, \nu^c, H, D^c, H^c, D, S^c)_L$$

$$\mathrm{SU}(5) : \mathbf{10} = (Q, u^c, e^c), \bar{\mathbf{5}} = (L, d^c), \mathbf{1} = (\nu^c), \bar{\mathbf{5}} = (H, D^c), \mathbf{5} = (H^c, D), \mathbf{1} = (S^c)$$

$$\text{`Conventional'}\ \mathrm{SO}(10) \ : \mathbf{16} = (Q, u^c, e^c, L, d^c, \nu^c)\ ,\ \mathbf{10} = (H, D^c, H^c, D)\ ,\ \mathbf{1} = (S^c)$$

$$\text{`Unconventional'}\ \mathrm{SO}(10) \ : \mathbf{16} = (Q, u^c, e^c, H, D^c, \nu^c), \mathbf{10} = (L, d^c, H^c, D)\ ,\ \mathbf{1} = (S^c)$$

From conventional to unconventional SO(10) (Nardi–Rizzo '94): $\theta \to \theta + \arctan\sqrt{15}$

U(1)' coupling and charges in the conventional assignments:

Model	θ
Z'_χ	$-\pi/2$
Z'_ψ	0
Z'_η	$\arccos\sqrt{5/8}$
Z'_I	$\arccos\sqrt{5/8}-\pi/2$
Z'_N	$\arctan\sqrt{15}-\pi/2$
Z'_S	$\arctan(\sqrt{15}/9)-\pi/2$

	$2\sqrt{10}\,Q_\chi$	$2\sqrt{6}\,Q_\psi$	$2\sqrt{15}\,Q_\eta$
Q	-1	1	2
u^c	-1	1	2
d^c	3	1	-1
L	3	1	-1
e^c	-1	1	2
ν_e^c	-5	1	5
H	-2	-2	-1
H^c	2	-2	-4
S^c	0	4	5
D	2	-2	-4
D^c	-2	-2	-1

$$g' = \sqrt{\frac{5}{3}}\, g_1 \quad ; \quad Q'(\Phi) = Q'_\psi(\Phi)\cos\theta - Q'_\chi(\Phi)\sin\theta$$

$$Q = (u \;\; d)_L \;,\; L = (e \;\; \nu_e)_L \;,\; D : \text{(s)quarks} \;,\; H : \text{(s)leptons},\; S : \text{singlet}$$

Assumption: **D and H are exotic quarks and leptons much heavier than the Z'**

ZZ' mixing is also neglected (J.Erler et al., JHEP09: $\sin\theta_{ZZ'} \sim 10^{-3}$-$10^{-4}$)

Minimal Supersymmetric Standard Model and U(1)'

The extra Z' requires a singlet Higgs to break U(1)' and get mass

$$\Phi_1 = \begin{pmatrix} \phi_1^0 \\ \phi_1^- \end{pmatrix} , \Phi_2 = \begin{pmatrix} \phi_2^+ \\ \phi_2^0 \end{pmatrix} , \Phi_3 = \phi_3^0 \quad , \quad Q'_i = Q'(\Phi_i)$$

Higgs sector after EWSB: h, H, A, $H^\pm$ (MSSM) and a new scalar H'

Three vacuum expectation values $v_i = \sqrt{2}\ \langle \phi_i^0 \rangle \quad v_1 < v_2 < v_3 \quad \tan\beta = v_2/v_1$

Gauginos: new $\tilde{Z}'$ and $\tilde{H}'$ lead to two new neutralinos, i.e. $\tilde{\chi}_1^0, \ldots \tilde{\chi}_6^0$

Chargino sector is unchanged, as the Z' is neutral

New Z' decay modes besides the SM ones:

$Z' \to \tilde{q}\tilde{q}^*$, $\tilde{\ell}^+\tilde{\ell}^-$, $\tilde{\nu}\tilde{\nu}^*$, $\tilde{\chi}_i^0\tilde{\chi}_j^0$, $\tilde{\chi}_{1,2}^+\tilde{\chi}_{1,2}^-$, ZH, Zh, ZA, H^+H^-, hA, HA, WW

Tree-level gaugino masses are obtained after diagonalizing the mass matrices in terms of the MSSM parameters M_1, M_2, M', $\tan\beta$, A_f, μ

Sfermion masses get D- and F-term corrections (m_0 soft mass at the Z' scale):

$$V(\phi,\phi^*) = F^{*i}F_i + \frac{1}{2}D^a D_a \ , \ D^a = -g^a(\phi^* T^a \phi) \ , \ F_i = \frac{\delta W}{\delta \phi_i}$$

First contribution to D-term (electroweak symmetry breaking):

$$\Delta\tilde{m}_a^2 = (T_{3,a}g_1^2 - Y_a g_2^2)(v_1^2 - v_2^2) = (T_{3,a} - Q_a \sin^2\theta_W) m_Z^2 \cos 2\beta$$

Second contribution driven by the new U(1)' symmetry:

$$\Delta\tilde{m}_a'^2 = \frac{g'^2}{2} Q_a'(Q_1' v_1^2 + Q_2' v_2^2 + Q_3' v_3^2)$$

$$\mathcal{M}_{\tilde{f}}^2 = \begin{pmatrix} (M_{\rm LL}^{\tilde{f}})^2 & (M_{\rm LR}^{\tilde{f}})^2 \\ (M_{\rm LR}^{\tilde{f}})^2 & (M_{\rm RR}^{\tilde{f}})^2 \end{pmatrix}$$

$$\begin{aligned}
(M_{\rm LL}^{\tilde{u}})^2 &= (m_{\tilde{u}_{\rm L}}^0)^2 + m_u^2 + \left(\frac{1}{2} - \frac{2}{3}x_w\right) m_Z^2 \ \cos 2\beta + \Delta\tilde{m}_{\tilde{u}_L}'^2 \\
(M_{\rm RR}^{\tilde{u}})^2 &= (m_{\tilde{u}_R}^0)^2 + m_u^2 + \left(\frac{1}{2} - \frac{2}{3}x_w\right) m_Z^2 \ \cos 2\beta + \Delta\tilde{m}_{\tilde{u}_R}'^2 \\
(M_{\rm LR}^{\tilde{u}})^2 &= m_u \left(A_u - \mu \cot\beta\right) .
\end{aligned}$$

Contributions $\sim m_u^2$ and mixing are inherited by the F-term

Representative Point:

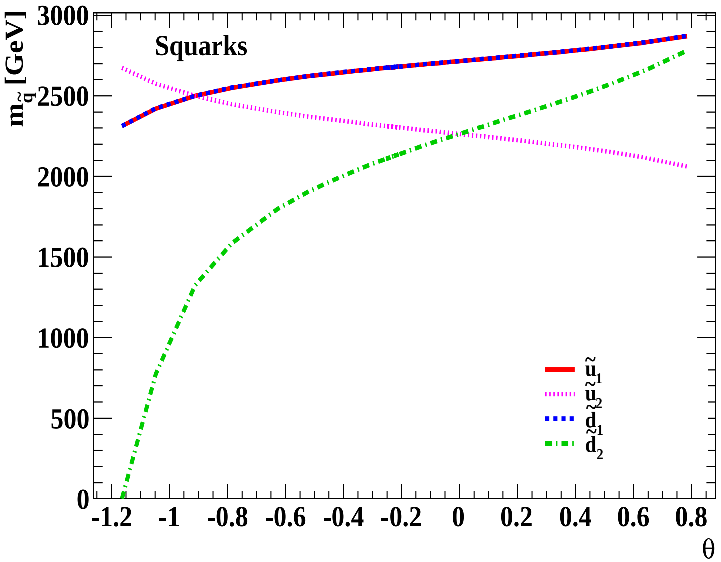
$$m_{Z'} = 3\ \text{TeV}\ ,\ \theta = \theta_I = \arccos\sqrt{\frac{5}{8}} - \frac{\pi}{2}$$

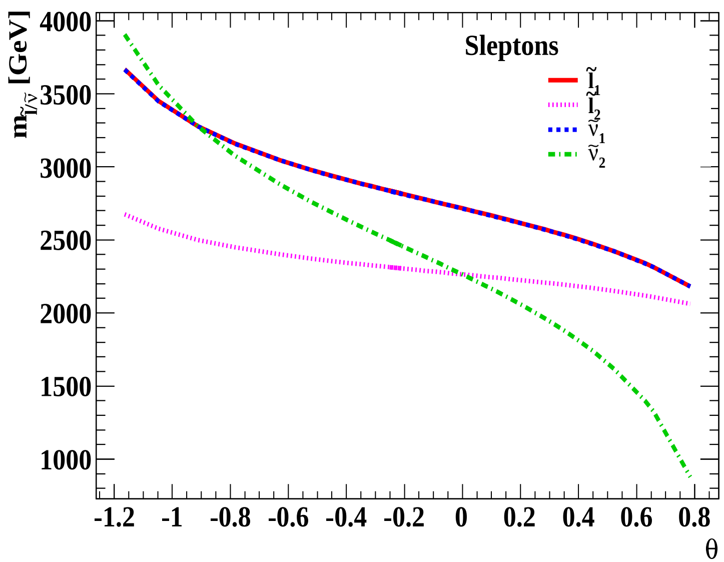
$$\mu = 200\ ,\ \tan\beta = 20\ ,\ A_q = A_\ell = A_f = 500\ \text{GeV}$$

$$m^0_{\tilde{q}_L} = m^0_{\tilde{q}_R} = m^0_{\tilde{\ell}_L} = m^0_{\tilde{\ell}_R} = m^0_{\tilde{\nu}_L} = m_{\tilde{\nu}_R} = 2.5\ \text{TeV}$$

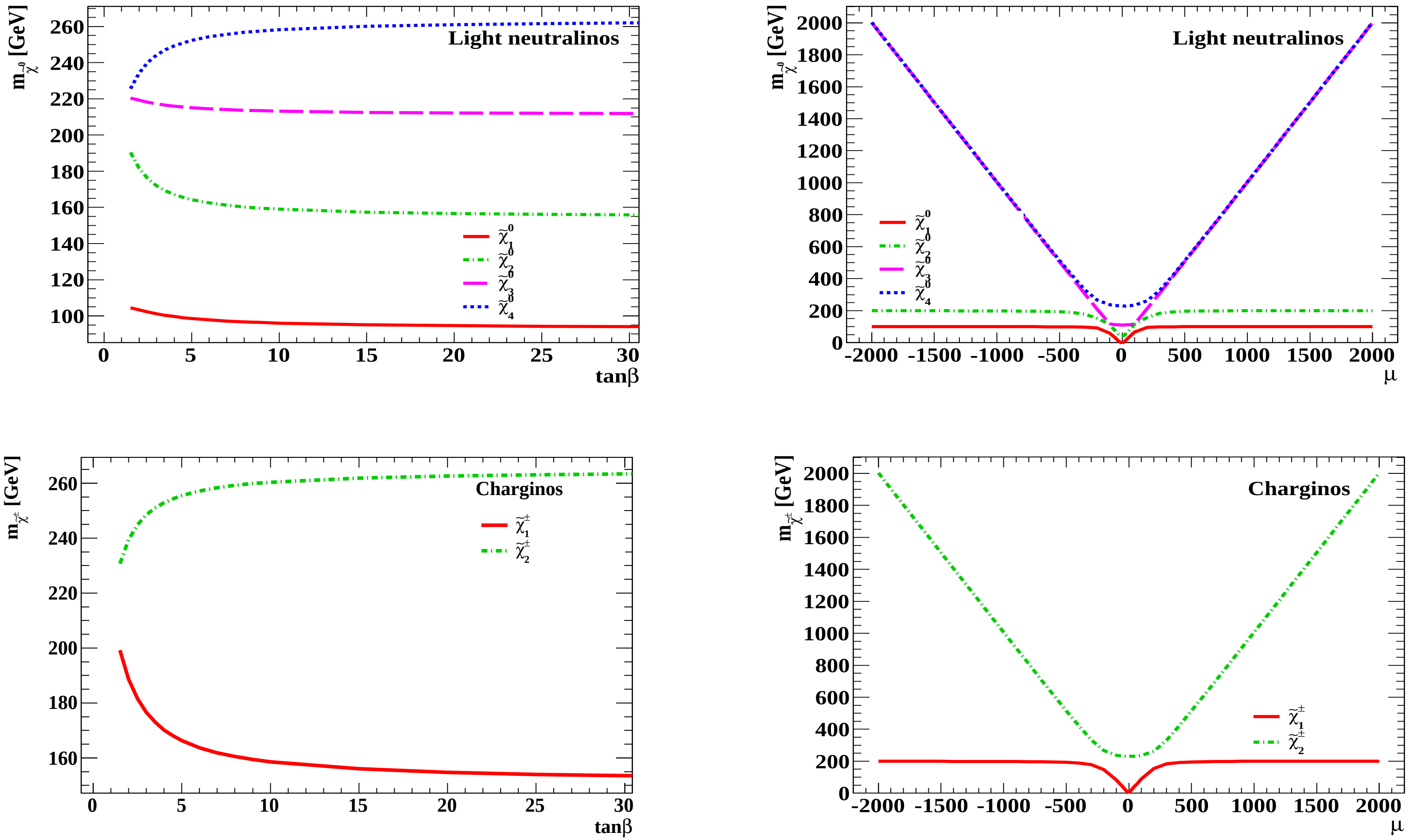
$$M_1 = 100\ \text{GeV}\ ,\ M_2 = 200\ \text{GeV}\ ,\ M' = 1\ \text{TeV}$$

$m_{\tilde{u}_1}$	$m_{\tilde{u}_2}$	$m_{\tilde{d}_1}$	$m_{\tilde{d}_2}$	$m_{\tilde{\ell}_1}$	$m_{\tilde{\ell}_2}$	$m_{\tilde{\nu}_1}$	$m_{\tilde{\nu}_2}$
2499.4	2499.7	2500.7	1323.1	3279.0	2500.4	3278.1	3279.1
$m_{\tilde{\chi}^0_1}$	$m_{\tilde{\chi}^0_2}$	$m_{\tilde{\chi}^0_3}$	$m_{\tilde{\chi}^0_4}$	$m_{\tilde{\chi}^0_5}$	$m_{\tilde{\chi}^0_6}$	$m_{\tilde{\chi}^\pm_1}$	$m_{\tilde{\chi}^\mp_2}$
94.6	156.5	212.2	260.9	2541.4	3541.4	154.8	262.1
m_h	m_A	m_H	$m_{H'}$	$m_{H^\pm}$			
90.7	1190.7	1190.7	3000.0	1193.4			





Dependence of neutralino and chargino spectra on MSSM parameters



Comparison with ISAJET: good agreement for Representative Point

Model	$m_{\tilde{\chi}_1^0}$	$m_{\tilde{\chi}_2^0}$	$m_{\tilde{\chi}_3^0}$	$m_{\tilde{\chi}_4^0}$	m_h	m_H	m_A	$m_{H^\pm}$	$m_{\tilde{\chi}_1^\pm}$	$m_{\tilde{\chi}_2^\pm}$
U(1)'/MSSM	94.6	156.6	212.2	261.0	90.7	1190.0	1190.0	1190.0	155.0	263.0
MSSM	91.3	152.2	210.2	266.7	114.1	1190.0	1197.9	1200.7	147.5	266.8

Lagrangian for Z' coupling with fermions

$$\mathcal{L}_f = g' \bar{f} \gamma^\mu (v_f - a_f \gamma_5) f Z'_\mu$$

$$v_f = \frac{1}{2}\left[Q'(f_L) + Q'(f_R)\right] = \frac{1}{2}\left[(Q'_\psi(f_L) + Q'_\psi(f_R))\cos\theta - (Q'_\chi(f_L) + Q'_\chi(f_R))\sin\theta\right]$$

$$a_f = \frac{1}{2}\left[Q'(f_L) - Q'(f_R)\right] = \frac{1}{2}\left[(Q'_\psi(f_L) - Q'_\psi(f_R))\cos\theta - (Q'_\chi(f_L) - Q'_\chi(f_R))\sin\theta\right]$$

Z' rate into fermions:

$$\Gamma(Z' \to f\bar{f}) = C_f \frac{g'^2}{12\pi} m_{Z'} \left[v_f^2 \left(1 + 2\frac{m_f^2}{m_{Z'}^2}\right) + a_f^2 \left(1 - 4\frac{m_f^2}{m_{Z'}^2}\right)\right] \left(1 - 4\frac{m_f^2}{m_{Z'}^2}\right)^{1/2}$$

Lagrangian for Z' coupling with sfermions

$$\mathcal{L}_{\tilde{f}} = g'(v_f \pm a_f)[\tilde{f}^*_{L,R}(\partial_\mu \tilde{f}_{L,R}) - (\partial_\mu \tilde{f}^*_{L,R})\tilde{f}_{L,R}] Z'^\mu$$

Z' rate into sfermions:

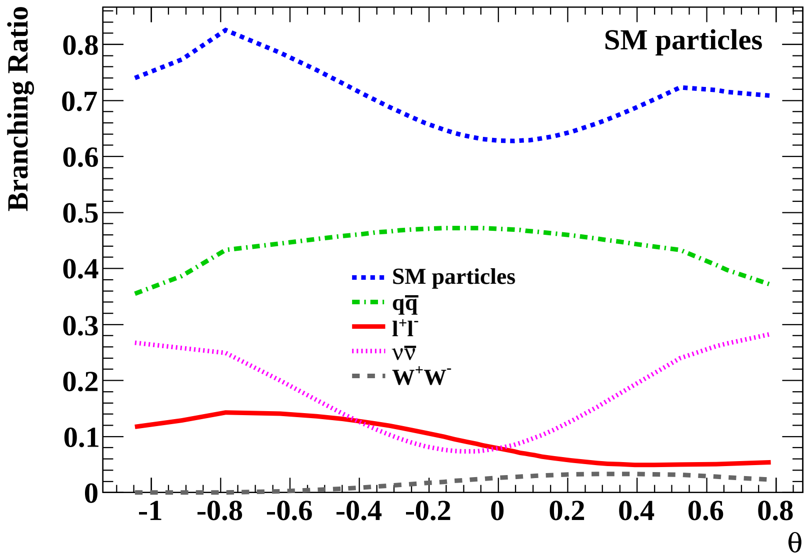
$$\Gamma(Z' \to \tilde{f}_{L,R}\tilde{f}^*_{L,R}) = C_f \frac{g'^2}{48\pi} m_{Z'} (v_f \pm a_f)^2 \left(1 - 4\frac{m_{\tilde{f}}^2}{m_{Z'}^2}\right)^{1/2}$$

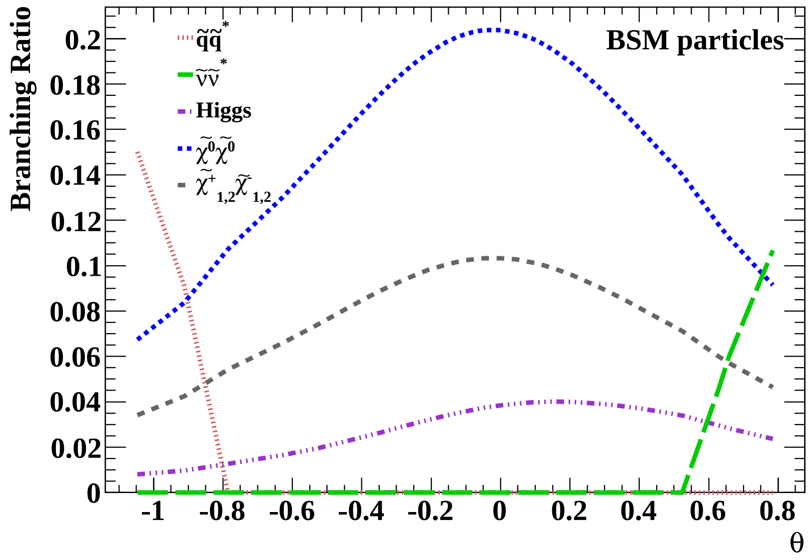
Zero rates into sfermions if $v_f = \pm a_f$, e.g. Z'_N and Z'_I couplings to $\tilde{f}_R \tilde{f}^*_R$

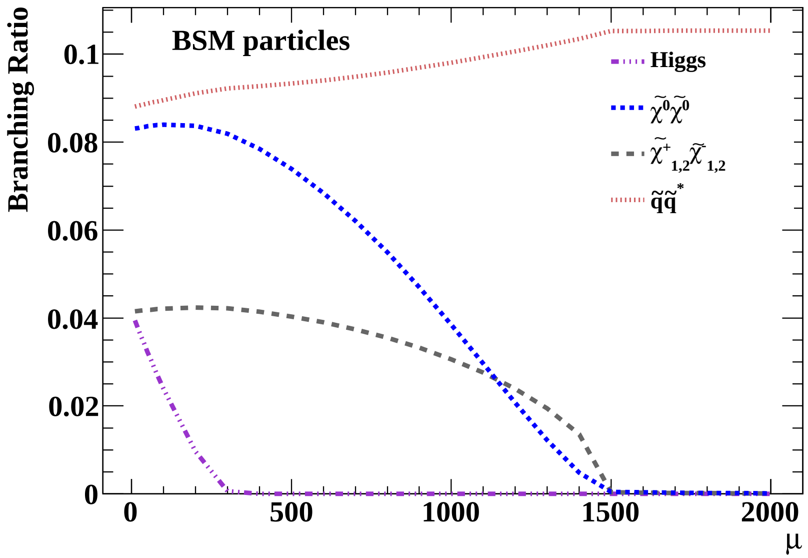
Branching ratios in the Representative Point

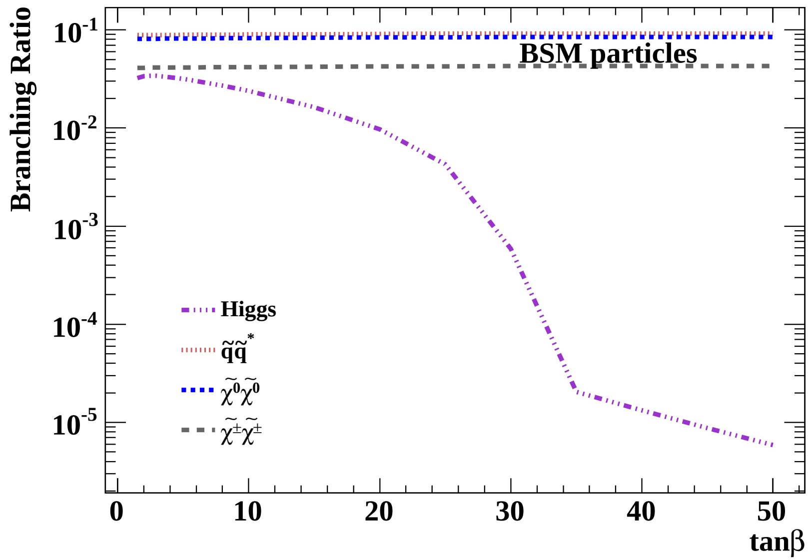
Final state	BR (%)	Final State	BR (%)
$\sum_i u_i \bar{u}_i$	0.00	$\tilde{\chi}_1^0 \tilde{\chi}_1^0$	0.07
$\sum_i d_i \bar{d}_i$	40.67	$\tilde{\chi}_1^0 \tilde{\chi}_2^0$	0.43
$\sum_i \ell_i^+ \ell_i^-$	13.56	$\tilde{\chi}_1^0 \tilde{\chi}_3^0$	0.71
$\sum_i \nu_i \bar{\nu}_i$	27.11	$\tilde{\chi}_1^0 \tilde{\chi}_4^0$	0.27
$\sum_{i,j} \tilde{u}_i \tilde{u}_j^*$	0.00	$\tilde{\chi}_1^0 \tilde{\chi}_5^0$	$\sim 10^{-6}$
$\sum_{i,j} \tilde{d}_i \tilde{d}_j^*$	9.58	$\tilde{\chi}_2^0 \tilde{\chi}_2^0$	0.65
$\sum_{i,j} \tilde{\ell}_i \tilde{\ell}_j^*$	0.00	$\tilde{\chi}_2^0 \tilde{\chi}_3^0$	2.13
$\sum_{i,j} \tilde{\nu}_i \tilde{\nu}_j^*$	0.00	$\tilde{\chi}_2^0 \tilde{\chi}_4^0$	0.80
$H^+ H^-$	0.50	$\tilde{\chi}_3^0 \tilde{\chi}_3^0$	1.75
hA	$\sim 10^{-3}$	$\tilde{\chi}_3^0 \tilde{\chi}_4^0$	1.31
HA	0.51	$\tilde{\chi}_3^0 \tilde{\chi}_5^0$	$\sim 10^{-6}$
ZH	$\sim 10^{-3}$	$\tilde{\chi}_4^0 \tilde{\chi}_4^0$	0.25
ZH'	0.00	$\tilde{\chi}_1^\pm \tilde{\chi}_2^\mp$	1.95
$H'A$	0.00	$\tilde{\chi}_2^\pm \tilde{\chi}_2^\mp$	0.54
$W^\pm H^\mp$	$\sim 10^{-3}$	$\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$	1.76

Branching ratios as a function of the U(1)′ and MSSM parameters

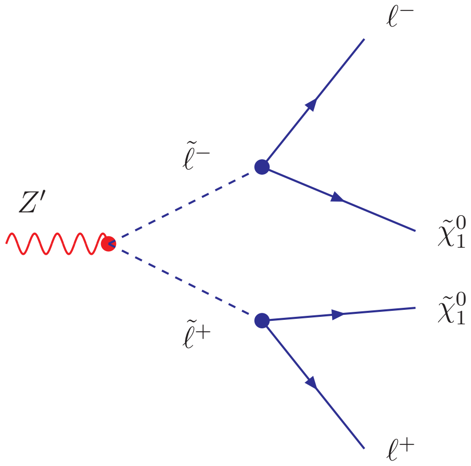


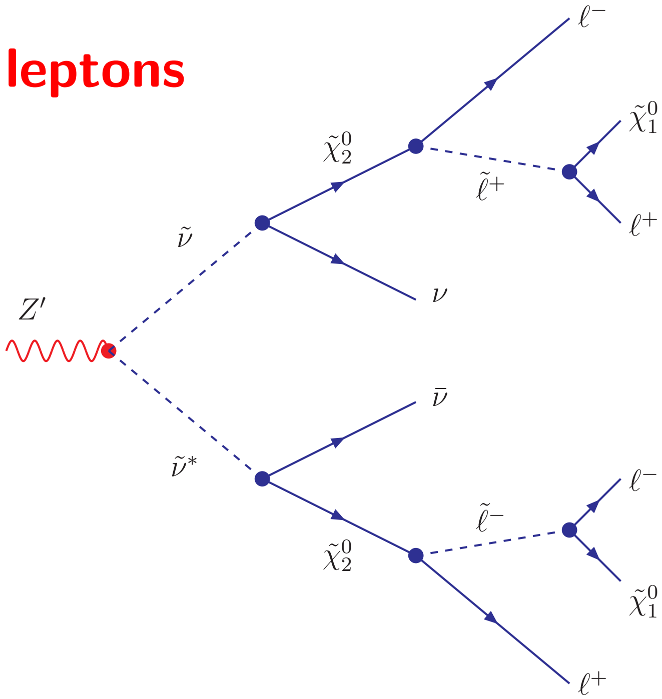


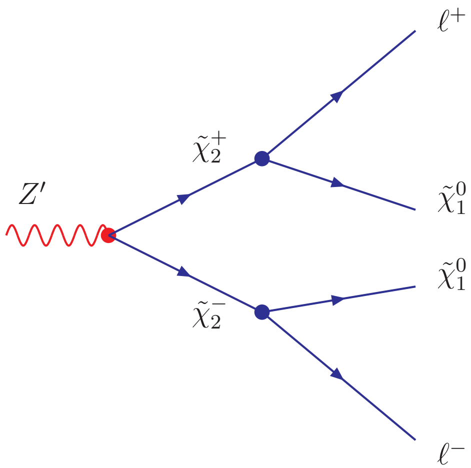


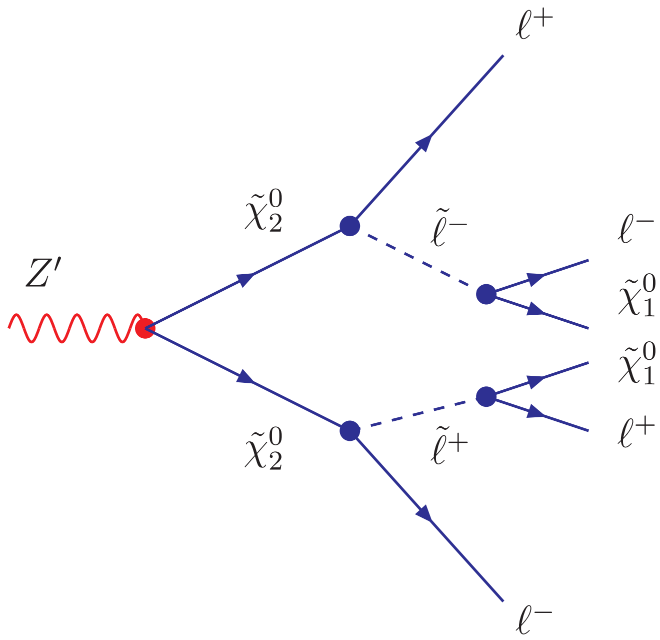


Z' decays into final states with leptons









Branching ratios into SM and BSM particles varying the Z' and slepton masses

$\mu = 200$, $\tan\beta = 20$, $A_q = A_\ell = 500$ GeV , $m^0_{\tilde{q}} = 5$ TeV , $M_1 = 150$ GeV , $M_2 = 300$ GeV , $M' = 1$ TeV

Z'_η $(\theta \simeq 0.66)$:

$m_{Z'}$	$m^0_{\tilde{\ell}}$	$B_{q\bar{q}}$	$B_{\ell\ell}$	$B_{\nu\nu}$	B_{WW}	B_{ZH}	$B_{\tilde{\chi}^+\tilde{\chi}^-}$	$B_{\tilde{\chi}^0\tilde{\chi}^0}$	$B_{\tilde{\nu}\tilde{\nu}^*}$	B_{SM}	B_{BSM}
1.0	0.8	39.45	5.24	27.26	3.01	2.91	4.92	8.64	8.54	71.96	28.04
1.0	0.9	43.14	5.73	29.81	3.30	3.18	5.38	9.45	0.00	78.68	21.32
2.0	1.5	37.97	4.91	25.54	2.66	2.64	5.33	10.33	10.61	68.42	31.58
2.0	1.8	42.47	5.49	28.57	2.98	2.95	5.96	11.56	0.00	76.54	23.46
3.0	2.2	37.60	4.84	25.17	2.59	2.59	5.38	10.61	11.14	67.60	32.40
3.0	2.6	42.31	5.45	28.32	2.92	2.91	6.06	11.94	0.00	76.08	23.92
4.0	2.9	37.41	4.81	25.00	2.56	2.56	5.39	10.70	11.38	67.22	32.78
4.0	3.5	42.22	5.43	28.21	2.89	2.89	6.08	12.07	0.00	75.85	24.15

Z'_ψ $(\theta = 0)$:

$m_{Z'}$	$m^0_{\tilde{\ell}}$	$B_{q\bar{q}}$	$B_{\ell\ell}$	$B_{\nu\nu}$	B_{WW}	B_{ZH}	$B_{\tilde{\chi}^+\tilde{\chi}^-}$	$B_{\tilde{\chi}^0\tilde{\chi}^0}$	$B_{\tilde{\nu}\tilde{\nu}^*}$	$B_{\tilde{\ell}\tilde{\ell}^*}$	B_{SM}	B_{BSM}
1.0	0.4	48.16	8.26	8.26	3.00	2.89	9.13	16.53	1.91	1.90	64.69	35.31
1.0	0.7	50.07	8.59	8.59	3.08	2.99	9.49	17.18	0.00	0.00	67.25	32.75
2.0	0.8	46.30	7.77	7.77	2.62	2.62	9.92	19.37	1.80	1.80	61.85	38.15
2.0	1.3	48.03	8.06	8.06	2.72	2.72	10.29	20.10	0.00	0.00	64.16	35.84
3.0	1.1	45.35	7.58	7.58	2.53	2.54	9.92	19.63	1.86	1.86	60.51	39.49
3.0	1.9	47.10	7.88	7.88	2.62	2.64	10.30	20.39	0.00	0.00	62.85	37.15
4.0	1.5	44.60	7.45	7.45	2.47	2.49	9.82	19.53	1.80	1.80	59.49	40.51
4.0	2.5	46.26	7.72	7.72	2.56	2.58	10.19	20.26	0.00	0.00	61.71	38.29
5.0	1.8	44.16	7.37	7.37	2.44	2.46	9.76	19.44	1.82	1.82	58.89	41.11
5.0	3.1	45.83	7.65	7.65	2.53	2.55	10.13	20.18	0.00	0.00	61.12	38.88

Z'_N $(\theta \simeq -0.25)$:

$m_{Z'}$	$m^0_{\tilde{\ell}}$	$B_{q\bar{q}}$	$B_{\ell\ell}$	$B_{\nu\nu}$	B_{WW}	B_{ZH}	$B_{\tilde{\chi}^+\tilde{\chi}^-}$	$B_{\tilde{\chi}^0\tilde{\chi}^0}$	$B_{\tilde{\ell}\tilde{\ell}}$	B_{SM}	B_{BSM}
1.0	0.4	49.51	11.98	9.59	1.71	1.68	8.71	15.78	1.04	71.08	28.92
1.0	0.6	50.03	12.11	9.69	1.73	1.69	8.80	15.94	0.00	71.83	28.17
2.0	0.7	47.50	11.36	9.08	1.53	1.54	9.44	18.46	1.08	67.94	32.06
2.0	1.2	48.02	11.48	9.18	1.54	1.55	9.55	18.66	0.00	68.68	31.32
3.0	1.0	46.43	11.30	8.86	1.47	1.49	9.43	18.66	1.08	66.36	33.64
3.0	1.8	46.94	11.20	8.96	1.49	1.50	9.53	18.86	0.00	67.09	32.91
4.0	1.3	45.42	10.83	8.66	1.43	1.45	9.29	18.47	1.07	64.91	35.09
4.0	2.4	45.91	10.94	8.75	1.45	1.47	9.39	18.67	0.00	65.61	34.39
5.0	1.6	44.90	10.70	8.56	1.41	1.43	9.21	18.35	1.06	64.15	35.85
5.0	3.1	45.38	10.81	8.65	1.43	1.45	9.31	18.55	0.00	64.84	35.16

Z'_I $(\theta \simeq -0.91)$:

$m_{Z'}$	$m^0_{\tilde{\ell}}$	$B_{q\bar{q}}$	$B_{\ell\ell}$	$B_{\nu\nu}$	$B_{H^+H^-}$	B_{WH}	B_{HA}	$B_{\tilde{\chi}^+\tilde{\chi}^-}$	$B_{\tilde{\chi}^0\tilde{\chi}^0}$	B_{SM}	B_{BSM}
1.0	1.0	44.06	14.69	29.37	0.00	$\mathcal{O}(10^{-3})$	$\mathcal{O}(10^{-4})$	4.31	7.58	88.11	11.89
1.5	1.0	43.39	14.46	28.93	0.00	$\mathcal{O}(10^{-4})$	$\mathcal{O}(10^{-4})$	4.56	8.65	86.78	13.22
2.0	1.0	43.16	14.38	28.77	0.00	$\mathcal{O}(10^{-4})$	$\mathcal{O}(10^{-3})$	4.65	9.03	86.31	13.69
2.5	1.0	42.99	14.33	28.66	0.06	$\mathcal{O}(10^{-3})$	0.07	4.68	9.19	85.98	14.02
3.0	1.0	42.53	14.18	28.36	0.53	$\mathcal{O}(10^{-3})$	0.53	4.66	9.20	85.07	14.93
3.5	1.0	42.16	14.05	28.11	0.91	$\mathcal{O}(10^{-3})$	0.92	4.64	9.19	84.33	15.67
4.0	1.0	41.90	13.96	27.93	1.20	$\mathcal{O}(10^{-3})$	1.21	4.62	9.17	83.79	16.21
4.5	1.0	41.70	13.90	27.80	1.40	$\mathcal{O}(10^{-3})$	1.41	4.61	9.16	83.40	16.60
5.0	1.0	41.56	13.85	27.71	1.56	0.01	1.57	4.60	9.15	83.12	16.88

Z'_S $(\theta \simeq -1.16)$:

$m_{Z'}$	$m^0_{\tilde{\ell}}$	$B_{q\bar{q}}$	$B_{\ell\ell}$	$B_{\nu\nu}$	B_{WW}	B_{ZH}	$B_{\tilde{\chi}^+\tilde{\chi}^-}$	$B_{\tilde{\chi}^0\tilde{\chi}^0}$	$B_{\tilde{\ell}\tilde{\ell}^*}$	$B_{\tilde{q}\tilde{q}^*}$	$B_{\rm SM}$	$B_{\rm BSM}$
1.0	0.2	42.29	13.70	34.57	0.15	0.14	3.33	5.75	0.07	0.00	90.56	9.44
2.0	0.2	41.67	13.48	34.02	0.14	0.14	3.57	6.90	0.08	0.00	89.17	10.82
3.0	0.2	41.25	13.34	33.66	0.14	0.14	3.58	7.06	0.08	0.00	88.25	11.75
4.0	0.2	40.81	13.20	33.30	0.14	0.14	3.56	7.07	0.08	0.00	87.30	12.70
5.0	0.2	37.34	12.07	30.46	0.13	0.13	3.27	6.50	0.07	7.97	79.87	20.12

Z'_χ $(\theta \simeq -1.57)$:

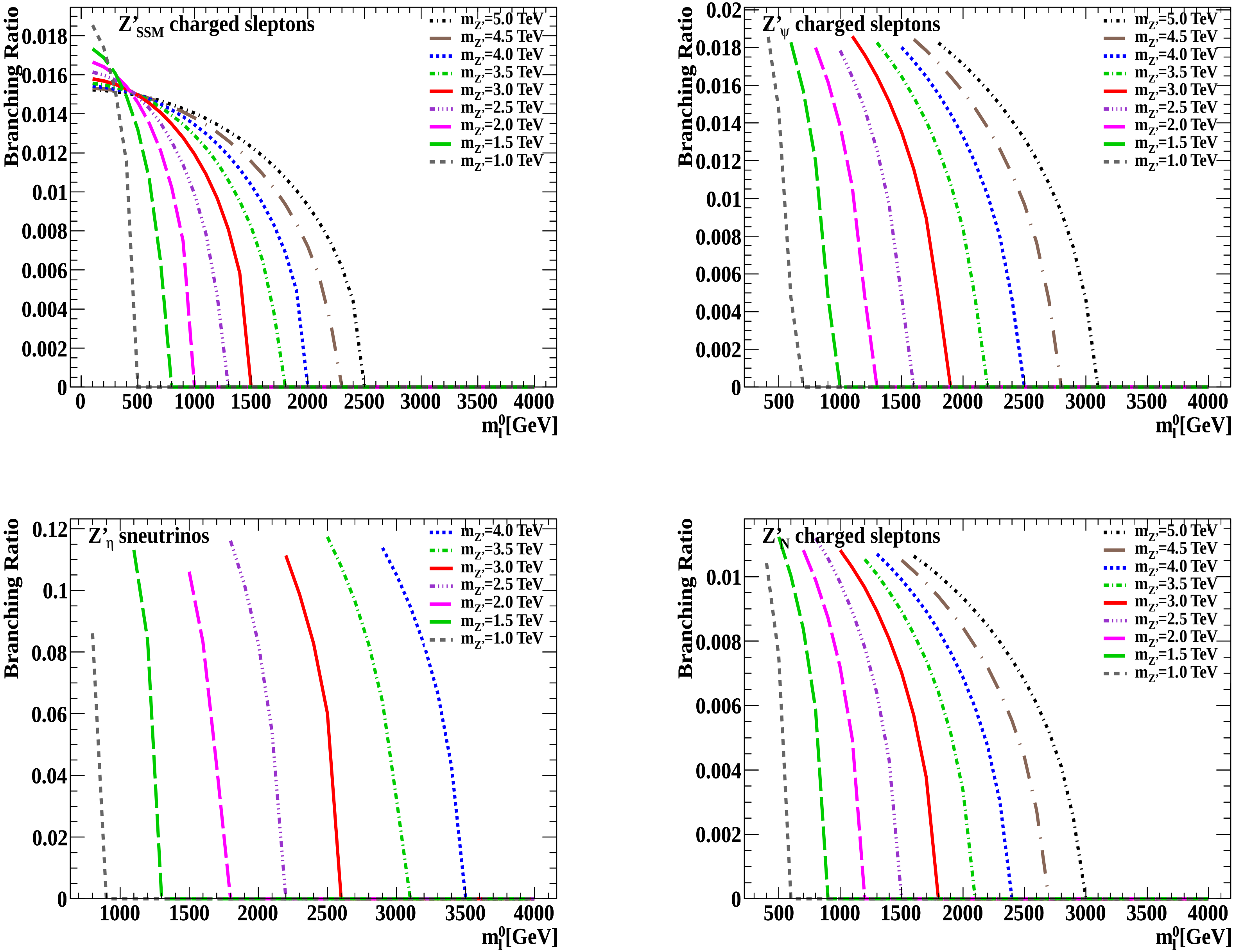
(unphysical sfermion spectrum)

$m_{Z'}$	$B_{q\bar{q}}$	$B_{\ell\ell}$	$B_{\nu\nu}$	B_{WW}	$B_{H^+H^-}$	B_{ZH}	B_{HA}	$B_{\rm SM}$	$B_{\rm BSM}$
1.0	44.35	12.44	42.29	0.90	0.00	0.02	$\mathcal{O}(10^{-3})$	99.08	0.92
2.0	44.32	12.34	41.96	0.84	0.00	0.28	0.26	98.62	1.38
3.0	44.03	12.24	41.63	0.82	0.24	0.53	0.52	97.89	2.11
4.0	43.84	12.18	41.43	0.82	0.46	0.64	0.63	97.45	2.55
5.0	43.74	12.15	41.33	0.81	0.58	0.70	0.69	97.22	2.78

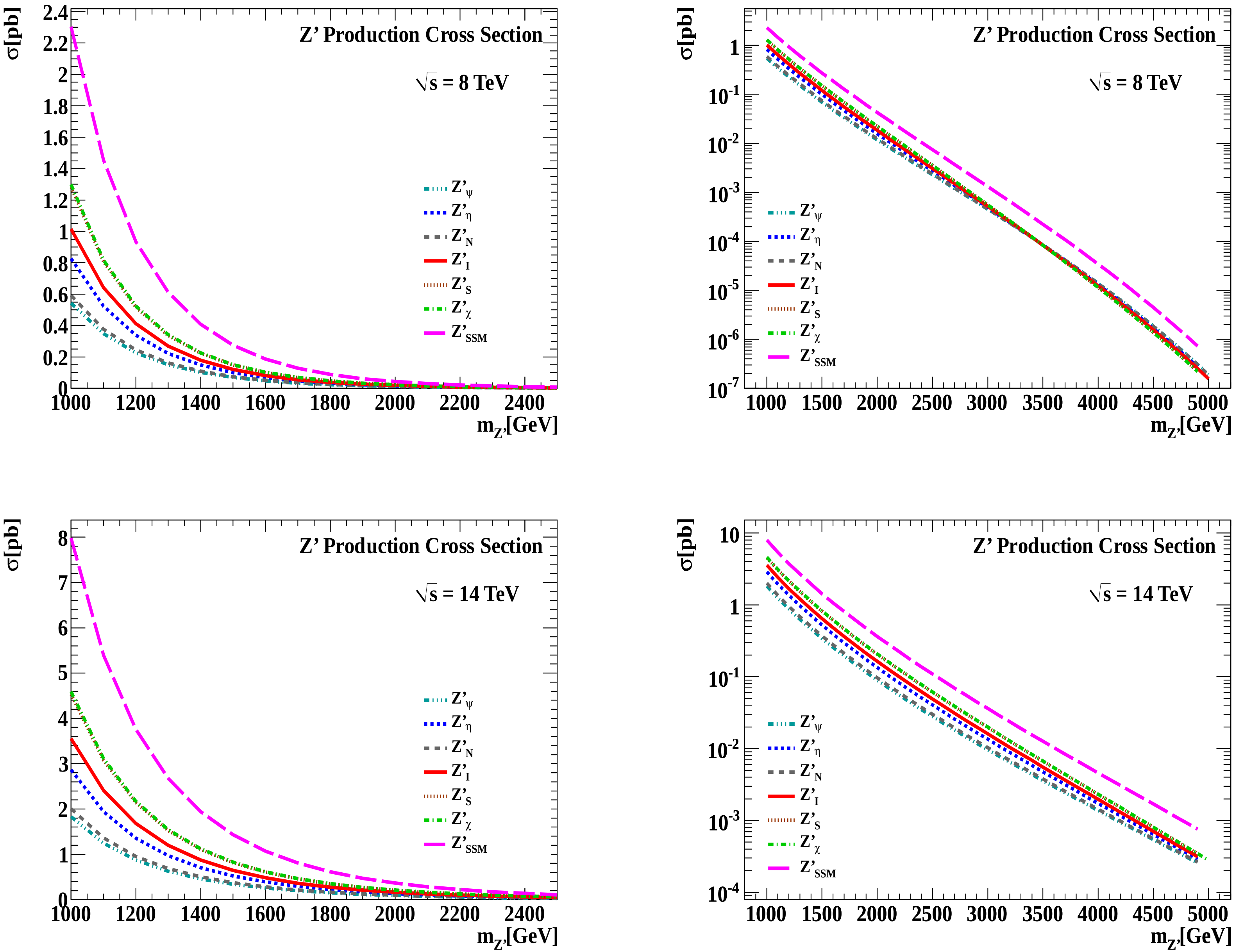
$Z'_{\rm SSM}$: $g' = g_2/(2\cos\theta_W)$

$m_{Z'}$	$m^0_{\tilde{\ell}}$	B_q	B_ℓ	B_ν	B_{WW}	B_{HH}	B_{Zh}	B_{hA}	$\mathsf{B}_{\chi^\pm}$	B_{χ^0}	$\mathsf{B}_{\tilde{\ell}}$	$\mathsf{B}_{\tilde{\nu}}$	$\mathsf{B}_{\rm SM}$	$\mathsf{B}_{\rm BSM}$
1.0	0.1	29.6	3.9	7.7	5.6	0.0	0.0	0.0	18.3	29.3	1.9	3.8	41.2	58.8
1.0	0.5	31.4	4.1	8.2	5.9	0.0	0.0	0.0	19.4	31.1	0.0	0.0	43.6	56.4
1.5	0.1	27.4	3.5	7.0	4.9	0.9	0.9	0.8	17.8	32.5	1.7	3.5	37.9	62.1
1.5	0.7	28.9	3.7	7.4	5.1	0.0	0.9	0.8	18.8	34.3	0.0	0.0	40.0	60.0
2.0	0.1	26.2	3.4	6.7	4.6	0.0	1.9	1.8	17.4	33.0	1.7	3.3	36.3	63.7
2.0	1.0	27.6	3.5	7.0	4.8	0.0	2.0	1.9	18.3	34.7	0.0	0.0	38.2	61.8
2.5	0.1	25.4	3.3	6.5	4.4	0.9	2.6	2.5	16.9	32.8	1.6	3.2	35.1	64.9
2.5	1.2	26.6	3.4	6.8	4.6	0.9	2.7	2.7	17.8	34.4	0.0	0.0	36.8	63.2
3.0	0.1	24.8	3.2	6.3	4.2	1.7	3.0	2.9	16.6	32.5	1.6	3.1	34.3	65.7
3.0	1.5	26.0	1.7	6.6	4.5	1.8	3.1	3.1	17.4	34.1	0.0	0.0	36.0	64.0
3.5	0.1	24.4	3.1	6.2	4.2	2.3	3.2	3.2	16.4	32.3	1.6	3.1	33.7	66.2
3.5	1.7	25.6	1.4	6.5	4.4	2.4	3.4	3.3	17.2	33.9	0.0	0.0	35.4	64.6
4.0	0.1	24.2	3.1	6.1	4.1	2.6	3.4	3.4	16.3	32.2	1.5	3.1	33.4	66.6
4.0	2.0	25.3	1.2	6.4	4.3	2.8	3.6	3.5	17.1	33.7	0.0	0.0	35.0	65.0
4.5	0.1	24.0	3.1	6.1	4.1	2.9	3.5	3.5	16.2	32.1	1.5	3.0	33.2	66.8
4.5	2.2	25.1	1.1	6.4	4.3	3.0	3.7	3.7	17.0	33.6	0.0	0.0	34.8	65.2
5.0	0.1	23.9	3.0	6.1	4.1	3.1	3.6	3.6	16.1	32.0	1.5	3.0	33.0	67.0
5.0	2.5	25.0	1.0	6.4	4.2	3.3	3.8	3.7	16.9	33.5	0.0	0.0	34.6	65.4

Dependence of branching ratios on Z' and slepton masses



Production cross sections in pp collisions $q\bar{q} \to Z'$, LO pdf CTEQ6L



Expected event numbers (narrow width approximation):

$$\sigma(pp \to Z' \to f_1 f_2) \simeq \sigma(pp \to Z') \times \mathrm{BR}(Z' \to f_1 f_2) \; ; \; \mathrm{N} = \mathcal{L}\sigma$$

Cascade events: $\mathrm{N_{casc}} = \mathrm{N}(\tilde{\nu}\tilde{\nu}^*) + \mathrm{N}(\tilde{\chi}^+\tilde{\chi}^-) + \mathrm{N}(\tilde{\chi}^0\tilde{\chi}^0)$

Charged-slepton events: $\mathrm{N_{slep}} = \mathrm{N}(\tilde{\ell}^+\tilde{\ell}^-)$

$\sqrt{s} = 8$ TeV $\mathcal{L} = 20\ \mathrm{fb}^{-1}$

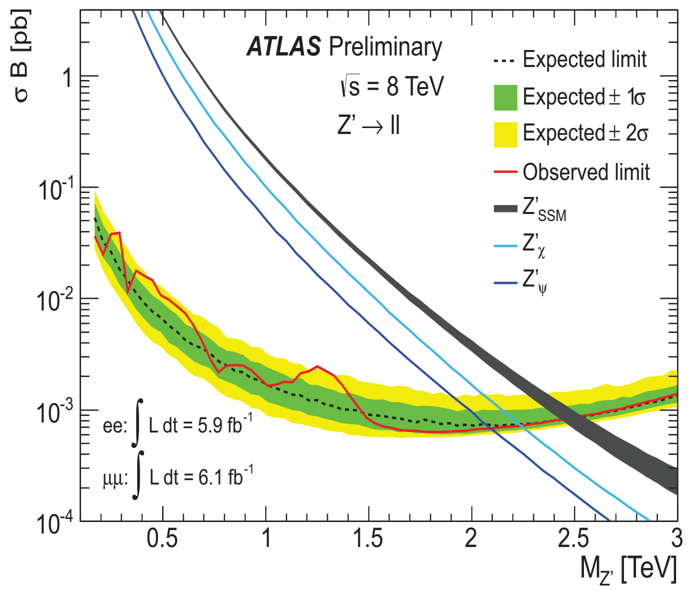
Model	$m_{Z'}$ (TeV)	$\mathrm{N_{casc}}$	$\mathrm{N_{slep}}$
Z'_η	1.5	523	–
Z'_η	2.0	55	–
Z'_ψ	1.5	599	36
Z'_ψ	2.0	73	4
Z'_N	1.5	400	17
Z'_N	2.0	70	3
Z'_I	1.5	317	–
Z'_I	2.0	50	–
Z'_S	1.5	30	–
Z'_S	2.0	46	–
Z'_SSM	1.5	2968	95
Z'_SSM	2.0	462	14

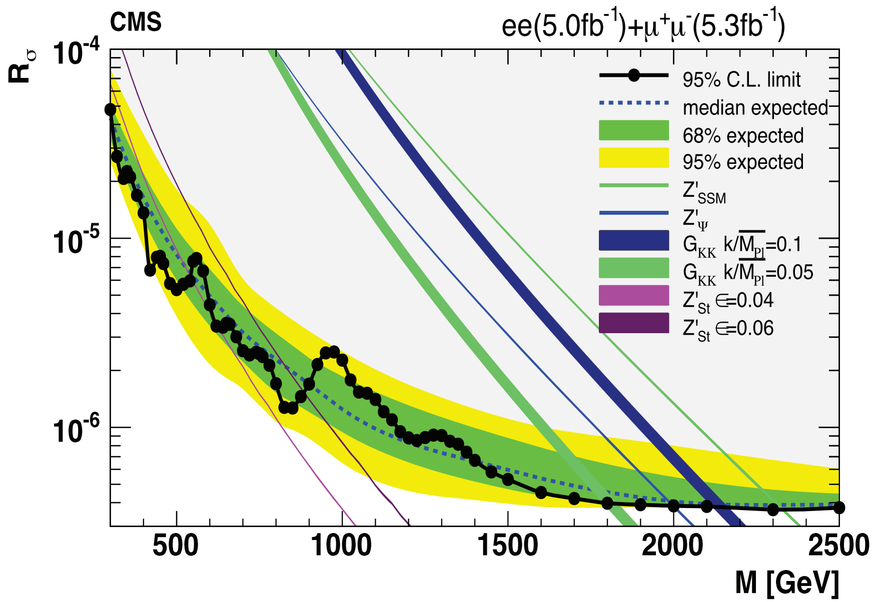
$\sqrt{s} = 14$ TeV $\mathcal{L} = 100\ \mathrm{fb}^{-1}$

Model	$m_{Z'}$ (TeV)	$\mathrm{N_{casc}}$	$\mathrm{N_{slep}}$
Z'_η	1.5	13650	–
Z'_η	2.0	2344	–
Z'_ψ	1.5	10241	622
Z'_ψ	2.0	2784	162
Z'_N	1.5	9979	414
Z'_N	2.0	2705	104
Z'_I	1.5	8507	–
Z'_I	2.0	2230	–
Z'_S	1.5	8242	65
Z'_S	2.0	2146	16
Z'_SSM	1.5	775715	24774
Z'_SSM	2.0	19570	606

Product $\sigma \times \mathrm{BR}$ to obtain the Z' mass exclusion limits

$$\mathrm{BR} = \mathrm{BR}(\mu^+\mu^-) + \mathrm{BR}(e^+e^-)$$





Left: ATLAS Electrons: $E_T > 35$ GeV, $\Delta R < 0.2$, $|\eta| < 2.5$ Muons: $E_T > 24$ GeV, $\Delta R < 0.3$, $|\eta| < 2.4$

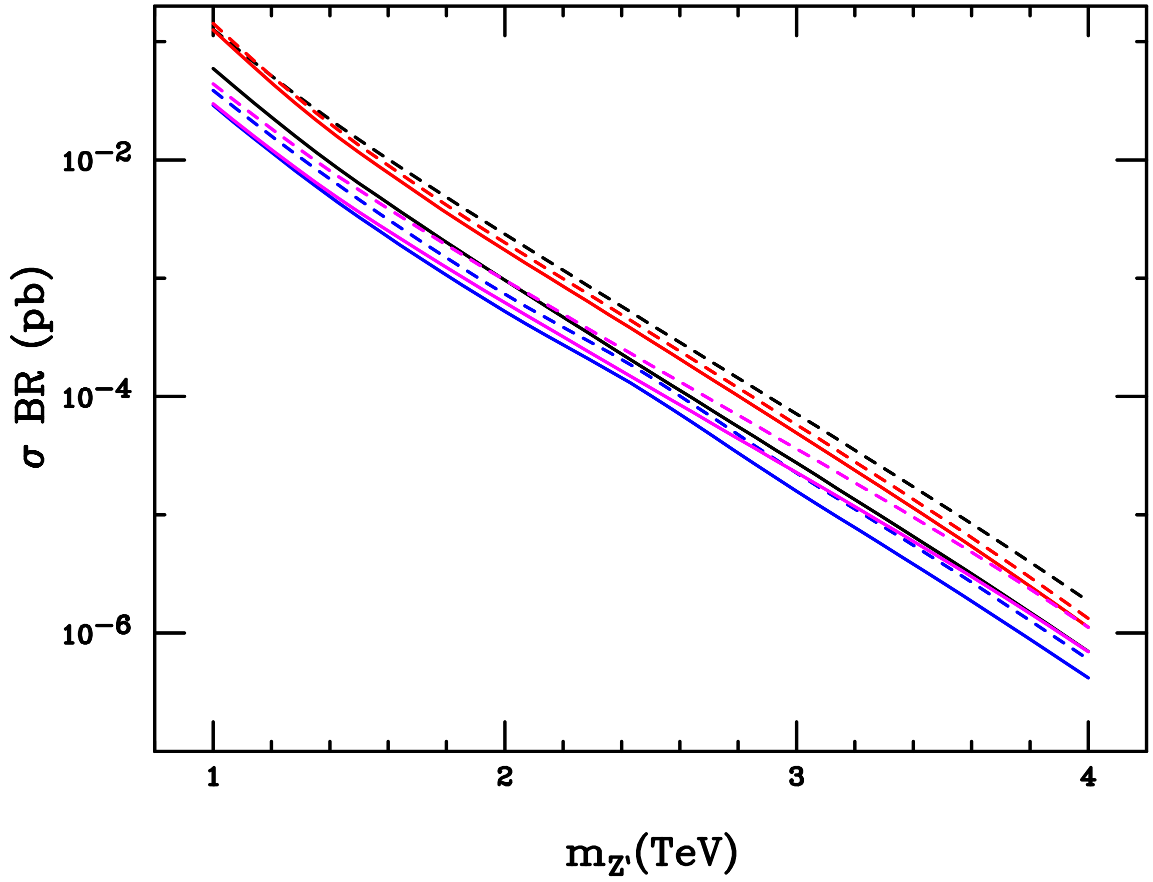
Right: CMS Electrons: $E_T > 35$ GeV, $\Delta R < 0.3$, $|\eta| < 1.44$ Muons: $E_T > 45$ GeV, $\Delta R < 0.3$, $|\eta| < 2.5$

Intersection of 1σ and 2σ bands with the theory curves yields the exclusion limits

CMS: $R_\sigma = (\sigma\ \mathrm{BR})_{Z'}/(\sigma\ \mathrm{BR})_Z$

Impact of BSM decays on the $\sigma\mathrm{BR}$ product

G.C., arXiv:1207.5424, Proceedings of Blois2012



Solid: SM+BSM decays ; Dashes: only SM decays

Black: $Z'_{\rm SSM}$; Blue: Z'_η; Red: $Z'_{\rm I}$; Magenta: Z'_ψ

Impact of inclusion of SUSY decays: $Z'_{\rm SSM}$ 60%; Z'_η: 30% ; $Z'_{\rm I}$: 13% ; Z'_ψ: 40%

Conclusions and outlook

Novel investigation on Z' phenomenology in supersymmetry at the LHC

BSM modes decrease SM rates; the Z' constrains sparticle invariant masses

Marrying U(1)' and MSSM: two extra neutralinos, one new neutral scalar Higgs, extra D-term contribution to sfermion masses

Studies of mass spectra, Z' branching ratios and production cross sections for a reference point in the parameter space

BSM branching ratios 10-30% for U(1)' groups and up to 60% for SSM

Up to $\mathcal{O}(10^5)$ supersymmetric events with sleptons and gauginos in the high-luminosity phase of the LHC, especially for SSM

In progress:

Implementation of the U(1)'/MSSM models in HERWIG: parton showers, Z' width effects, hadronization and acceptance cuts on jets and leptons

Background estimation (ALPGEN)

Interplay of SUSY/exotics LHC groups to choose SUSY/U(1)' points

Revisiting the limits on the Z' mass