Testing supergravity models with heavy scalars at the HL-LHC and HE-LHC and the gravitino decay constraints

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Introduction

- In models where the LSP is bino-like, coannihilation is needed to deplete the relic density to $\Omega h^2 = 0.1197 \pm 0.0022$ [Planck Collaboration, arXiv:1502.01589 [astro-ph.CO]]
- Coannihilation requires the mass gap between the LSP and the NLSP be small (typically $\lesssim 20$ GeV)
- Relic density is controlled by the ratio

$$\delta_i = \frac{n_i^{eq}}{n^{eq}} = \frac{g_i(1+\Delta_i)^{3/2}e^{-\Delta_i x}}{\sum_j g_j(1+\Delta_j)^{3/2}e^{-\Delta_j x}},$$

where $\Delta_i = (m_i - m_1)/m_1$, g_i are the degrees of freedom of χ_i and $x = m_1/T$. The relic density involved in the integral

$$J_{x_f} = \int_{x_f}^{\infty} x^{-2}\langle\sigma_{eff} v\rangle dx.$$

SUGRA models

- In previous works, stop[1], gluino[2] and stau[3] coannihilation have been discussed.

  [1][B. Kaufman, P. Nath, B. Nelson, A. Spisak, arXiv:1509.02530v2 [hep-ph]]

  [2][P. Nath, A. Spisak, arXiv:1603.04854v2 [hep-ph]]

  [3][A. Aboubrahim, P. Nath, and A. Spisak, arXiv:1704.04669 [hep-ph]]

- Here we extend the study to chargino coannihilation models. To achieve chargino coannihilation we need non-universal SUGRA: $m_0\,, A_0\,, m_1\,, m_2\,, m_3\,,\ \tan\beta\,, \text{sign}(\mu)$

- For the case of heavy gluinos and lighter electroweakinos one has $m_3 >> m_1 > m_2$ while for electroweakinos and gluinos with masses $\mathcal{O}(1)$ TeV one has $m_1 > m_2 >> m_3$

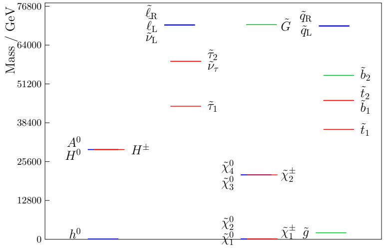
Advantages of heavy scalars?

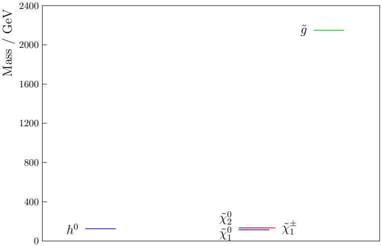
- Scalar masses in the 50-100 TeV range produce unification of gauge coupling constants, consistent with experimental data at low scale
- Decay of the gravitinos with mass order m_0 happens before the Big Bang Nucleosynthesis (BBN)
- SUGRA models with scalar masses in the range 50-100 TeV have several other attractive features such as they help alleviate the SUSY CP problem and help suppress proton decay from baryon and lepton number violating dimension five operators

Sparticle mass hierarchies

- With a small available mass gap between the LSP and the NLSP, decay products are soft. Switch on ISR and FSR
- An exhibition of the sparticle mass hierarchy for a representative model point. Left panel: entire mass spectrum. Right panel: lighter gauginos and the Higgs boson

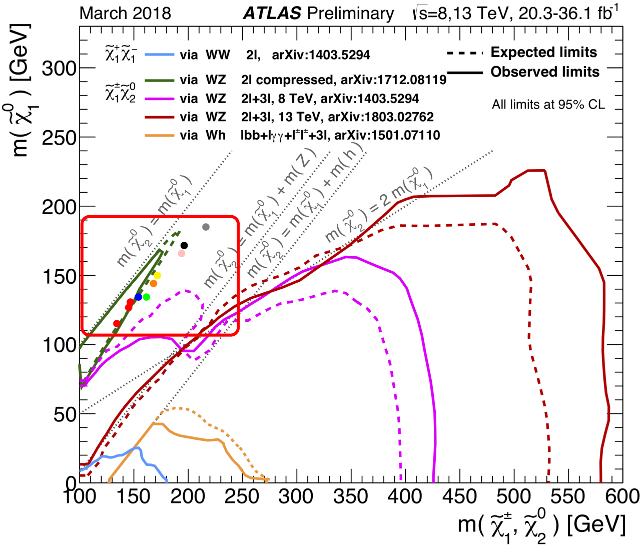
[A. Aboubrahim, P. Nath, arXiv:1708.02830 [hep-ph]]



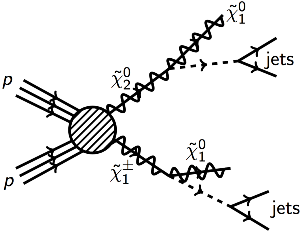


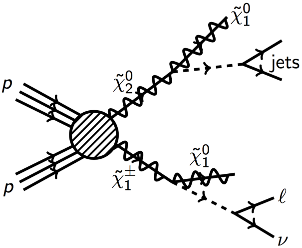
- Table of benchmark points used in the analysis of chargino coannihilation, satisfying the Higgs mass and relic density constraints

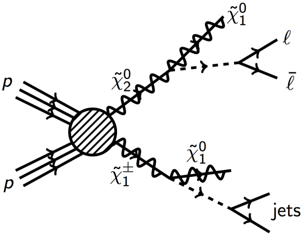
Model	m_0	A_0	m_1	m_2	m_3	$\tan\beta$
(a)	70760	141410	544	481	983	45
(b)	77710	155593	503	426	1645	11
(c)	92390	183892	557	474	1441	18
(d)	82900	165862	539	466	1275	6
(e)	63057	126110	504	414	1472	28
(f)	67248	134496	543	446	1482	30
(g)	54981	109990	521	419	1388	34
(h)	86618	172526	610	497	1369	23
(i)	58619	117055	550	425	1204	25
(j)	74199	148386	620	487	1000	27


March 2018
ATLAS Preliminary
√s=8,13 TeV, 20.3-36.1 fb⁻¹
$\tilde{\chi}_1^+\tilde{\chi}_1^-$ via WW 2l, arXiv:1403.5294
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via WZ 2l compressed, arXiv:1712.08119
via WZ 2l+3l, 8 TeV, arXiv:1403.5294
via WZ 2l+3l, 13 TeV, arXiv:1803.02762
via Wh lbb+lγγ+l±l±+3l, arXiv:1501.07110
Expected limits
Observed limits
All limits at 95% CL
$m(\tilde{\chi}_2^0) = m(\tilde{\chi}_1^0)$
$m(\tilde{\chi}_2^0) = m(\tilde{\chi}_1^0) + m(Z)$
$m(\tilde{\chi}_2^0) = m(\tilde{\chi}_1^0) + m(h)$
$m(\tilde{\chi}_2^0) = 2\,m(\tilde{\chi}_1^0)$
$m(\tilde{\chi}_1^0)$ [GeV]
$m(\tilde{\chi}_1^\pm, \tilde{\chi}_2^0)$ [GeV]
0
50
100
150
200
250
300
100
150
200
250
300
350
400
450
500
550
600

Three signal regions: zero, single and two lepton channels along with jets and missing transverse energy in the final state







- Searches based on two categories of final states:
    - Zero leptons, jets and missing transverse energy
    - Single and two light leptons along with jets
- The SUSY production cross section for all models is dominated by the production of the neutralino-chargino pair, $\tilde{\chi}_2^0\tilde{\chi}_1^\pm$
- The decay channels in nearly every model point:
    - $\text{Br}(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 q\bar{q}) \sim 0.75$ and $\text{Br}(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \ell\bar{\ell}) \sim 0.25$
    - $\text{Br}(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 q_i\bar{q}_j) \sim 0.67$ and $\text{Br}(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 \ell^\pm \nu_\ell) \sim 0.33$

Estimated integrated luminosities for a 5σ discovery

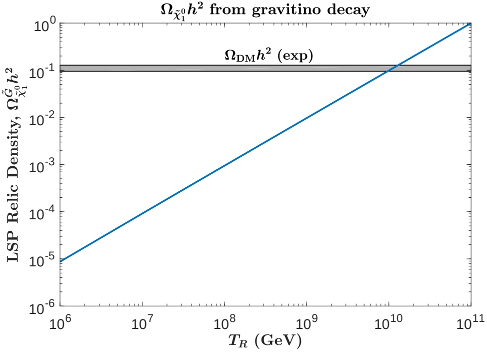
Points (a), (b) and (c) have already been excluded

Model	Leading SR	$\mathcal{L}$ (fb^{-1})	Sub-leading SR	$\mathcal{L}$ (fb^{-1})
(g)	$0\ell4j$-A	63 ± 8	$0\ell4j$-B	147 ± 19
(e)	$0\ell4j$-A	74 ± 10	$0\ell2j$-A	83 ± 9
(a)	$1\ell2j$-C	80 ± 9	$0\ell2j$-A	86 ± 9
(b)	$2\ell1j$-SF-C	93 ± 16	$0\ell2j$-A	150 ± 17
(c)	$0\ell2j$-A	114 ± 13	$0\ell4j$-A	749 ± 84
(f)	$2\ell1j$-SF-C	126 ± 22	$0\ell2j$-A	173 ± 19
(d)	$0\ell2j$-A	174 ± 19	$2\ell1j$-SF-C	243 ± 43
(h)	$0\ell4j$-A	337 ± 44	$0\ell2j$-A	558 ± 63
(i)	$2\ell1j$-SF-C	504 ± 89	$2\ell1j$-SF-B	616 ± 109
(j)	$0\ell2j$-A	771 ± 87	$2\ell1j$-SF-B	2190 ± 387

- A gravitino has many decay final states to the MSSM states which include the dominant two body decays

$$\tilde{G} \to \tilde{g}g,\ \tilde{\chi}_1^{\pm}W^{\mp},\ \tilde{\chi}_1^0\gamma,\ \tilde{\chi}_1^0 Z$$

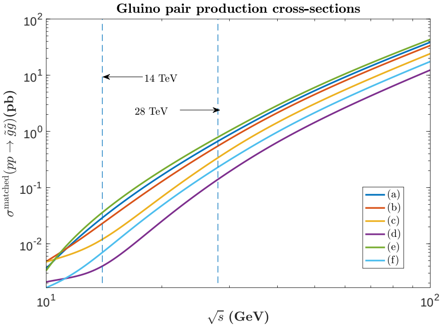
- At a reheat temperature $T_R \sim 10^9$ GeV, the contribution from non-thermal neutralinos to the relic density is negligible

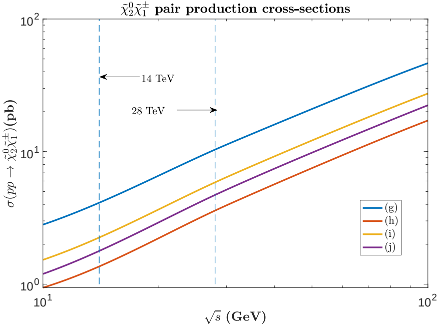


The 28 TeV collider: HE-LHC

- The High Energy LHC (HE-LHC) has been recently proposed as the next generation *pp* collider at CERN
- Uses the existing LHC ring with 16 T FCC magnets replacing the current 8.3 T ones
- Center-of-mass energy boosted to 28 TeV with a design luminosity $\sim$ 4 times that of the HL-LHC
- This set up necessarily means that a larger part of the parameter space of supersymmetric models beyond the reach of the 14 TeV collider will be probed

- Production cross-section of $\tilde{g}\tilde{g}$ at 28 TeV is $\sim 20 - 30$ times that at 14 TeV
- An increase by ~ 2.5 folds is seen for the case of electroweakino production



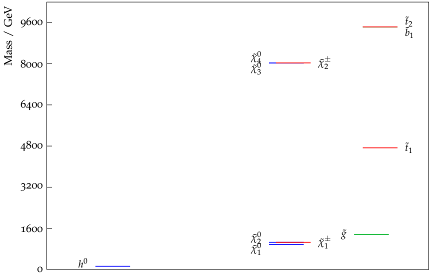


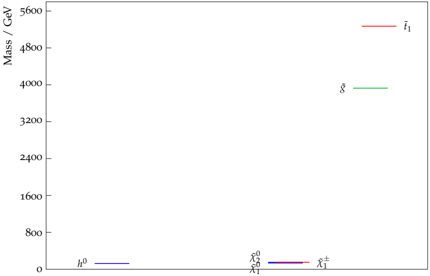
- The ten benchmark points satisfying the Higgs boson mass and relic density constraints

Model	m_0	A_0	m_1	m_2	m_3	$\tan\beta$
(a)	13998	30376	2155	1249	556	28
(b)	9528	22200	2281	1231	573	34
(c)	9288	20898	2471	1411	620	40
(d)	28175	62830	2634	1541	751	41
(e)	20335	44737	2459	1133	550	24
(f)	22648	50505	2700	1585	675	15
(g)	16520	37224	385	274	1685	16
(h)	48647	106537	537	432	2583	26
(i)	14266	-28965	371	224	2984	20
(j)	41106	108520	687	599	7454	42

SUGRA benchmarks (a)-(f) chosen with gluino and electroweakino masses $\mathcal{O}(1)$ TeV while points (g)-(j) have heavier gluinos and lighter electroweakinos

[A. Aboubrahim, P. Nath, arXiv:1804.08642 [hep-ph]]

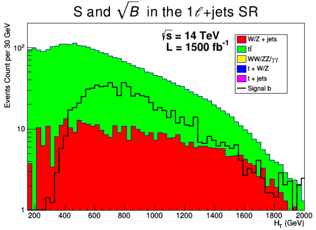


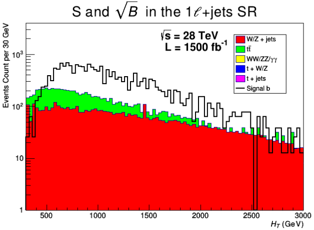


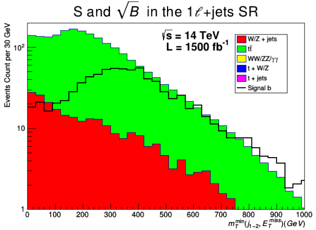
Benchmarks (a) [left] and (g) [right]

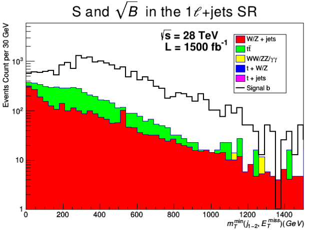
- Signal regions (SR) used in this analysis correspond to the single lepton, two lepton (same flavor opposite sign leptons, SFOS) and the three lepton channel
- Each SR has two classes of selection criteria, one targeting final states from gluino decay and the other suitable for soft final states from electroweakino pair decay
- Dominant decay channels of the gluino:
  $\text{Br}_{[\text{b}-\text{f}]}(\tilde{g} \to \tilde{\chi}_1^0 q\bar{q}) \sim (0.33 - 0.73)$ and
  $\text{Br}_{[\text{f}-\text{e}]}(\tilde{g} \to \tilde{\chi}_1^\pm q_i\bar{q}_j) \sim (0.20 - 0.63)$,
  $\text{Br}_{[\text{e}-\text{a},\text{d},\text{f}]}(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 W^\pm) \sim (0.23 - 1.0)$
- Dominant decay channels of the electroweakinos:
  $\text{Br}_{[\text{i}-\text{j}]}(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 q\bar{q}) \sim (0.68 - 0.94)$,
  $\text{Br}_{[\text{j}-\text{i}]}(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \ell\bar{\ell}) \sim (0.06 - 0.32)$
  Chargino decay modes are similar to previous analysis

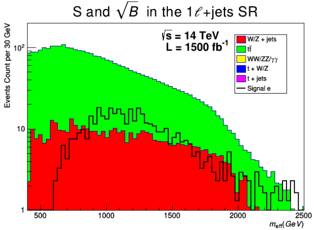
Integrated luminosities at HL-LHC vs HE-LHC

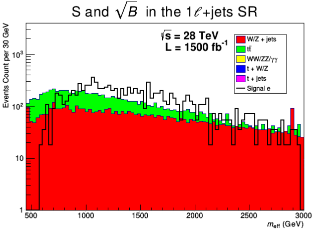


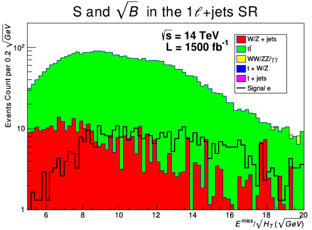


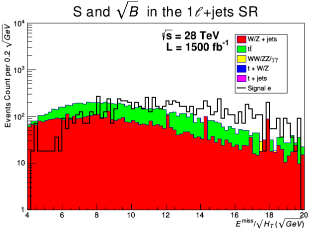




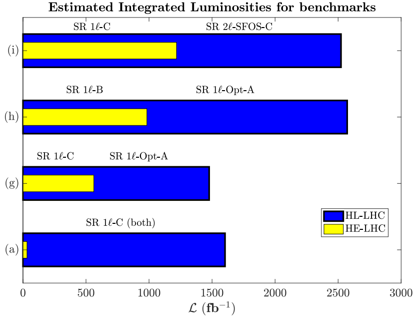

S and $\sqrt{B}$ in the 1ℓ+jets SR
$\sqrt{s}$ = 14 TeV
L = 1500 fb^{-1}
W/Z + jets
$t\bar{t}$
WW/ZZ/γγ
t + W/Z
t + jets
Signal e
Events Count per 30 GeV
$m_{\rm eff}$(GeV)

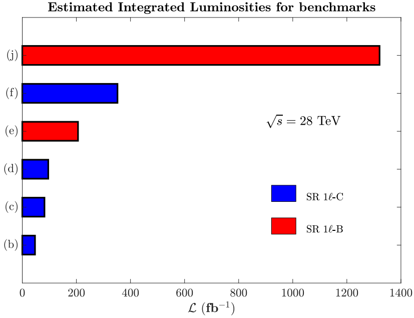

S and $\sqrt{B}$ in the 1ℓ+jets SR
$\sqrt{s}$ = 28 TeV
L = 1500 fb^{-1}
W/Z + jets
$t\bar{t}$
WW/ZZ/γγ
t + W/Z
t + jets
Signal e
Events Count per 30 GeV
$m_{\rm eff}$ (GeV)


S and $\sqrt{B}$ in the 1ℓ+jets SR
$\sqrt{s}$ = 14 TeV
L = 1500 fb^{-1}
W/Z + jets
$t\bar{t}$
WW/ZZ/γγ
t + W/Z
t + jets
Signal e
Events Count per 0.2 $\sqrt{GeV}$
$E^{\rm miss}/\sqrt{H_T}$ ($\sqrt{GeV}$)


S and $\sqrt{B}$ in the 1ℓ+jets SR
$\sqrt{s}$ = 28 TeV
L = 1500 fb^{-1}
W/Z + jets
$t\bar{t}$
WW/ZZ/γγ
t + W/Z
t + jets
Signal e
Events Count per 0.2 $\sqrt{GeV}$
$E^{\rm miss}/\sqrt{H_T}$ ($\sqrt{GeV}$)

The discovery of points (a), (g), (h) and (i) would require a run of HL-LHC for ∼ 5 yr for (a) and (g), and ∼ 8 yr for (h) and (i). The run period for discovery of these at HE-LHC will be ∼ 2 weeks for (a), ∼ 4 months for (g), ∼ 1 yr for (h) and ∼ 1.5 yr for (i) using the projection that HE-LHC will collect 820 fb^{-1} of data per year





Conclusion

- The parameter space satisfying the Higgs boson mass constraint mostly gives a neutralino which is bino-like. Hence coannihilation is needed to achieve the correct relic density
- Because of small mass gaps between the LSP and NLSP, supersymmetric signals arising from chargino coannihilation regions are hard to detect at colliders since the decay products are soft
- We have shown that such models can be tested by the end of LHC-II and at HL-LHC which is expected to reach an integrated luminosity of 3000 fb^{-1}
- It is found that SUSY discovery at HE-LHC would take a much shorter time reducing the run period of 5-8 yr at HL-LHC to a run period of few weeks to ~ 1.5 yr at HE-LHC
- HE-LHC is a powerful tool for the discovery of supersymmetry and deserves serious consideration

BACKUP SLIDES

Supergravity Models with 50-100 TeV Scalars, SUSY Discovery at the LHC and Gravitino Decay Constraints

- Signal region based on zero leptons, jets and missing transverse energy in the final state

Vetos

A veto on muons and electrons with leading jets required to have $p_T > 40$ GeV and sub-leading jets have $p_T > 20$ GeV.

Missing Energy

Pre-selection cut on the missing energy is applied:
$E_T^{\text{miss}} > 100$ GeV.

- $m_{\text{eff}} = \sum_i (p_T^{\text{jets}})_i + E_T^{\text{miss}} + \sum_i (p_T^{\ell})_i$
- $m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T}}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}) = \sqrt{2(p_{\mathrm{T}}\, E_{\mathrm{T}}^{\mathrm{miss}} - \mathbf{p}_{\mathrm{T}} \cdot \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})}$
- $m_{\mathrm{T2}} = \min\left[\max\left(m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T}}(\ell_1), \mathbf{q}_{\mathrm{T}}), m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T}}(\ell_2), \mathbf{p}_{\mathrm{T}}^{\text{miss}} - \mathbf{q}_{\mathrm{T}})\right)\right]$

- In the single lepton channel, one prompt light lepton (electron or muon) is selected such that $|\eta| < 1.4$ for electrons and $|\eta| < 1.2$ for muons
- We require that $\Delta\phi(\vec{\ell}, \vec{p}_T^{\text{miss}}) > 1.5$ rad to avoid misidentification of $\vec{p}_T^{\text{miss}}$ with leptons
- Two lepton final state: 2ℓ-SF (same flavor opposite sign) and 2ℓ-DF (different flavor opposite sign)
- 2ℓ-DFOS arises from the decay of a $\tilde{\chi}_1^+\tilde{\chi}_1^-$ pair
- Events containing two leptons are selected such that the leading and the sub-leading lepton transverse momenta must be $p_T^\ell > 15$ GeV and 10 GeV, respectively

The selection criteria used for the zero lepton channel

Requirement	$0\ell nj$					
	$0\ell 2j$-A	$0\ell 2j$-B	$0\ell 2j$-C	$0\ell 4j$-A	$0\ell 4j$-B	$0\ell 4j$-C
N(jets)	≥ 2	≥ 2	≥ 2	≥ 4	≥ 4	≥ 4
$p_T(j_1)$ (GeV) $<$	100	100	100	100	100	100
$p_T(j_2)$ (GeV) $<$	60	60	60	80	80	80
$p_T(j_4)$ (GeV) $<$				50	50	50
$E_T^{\rm miss}$(GeV) $<$	250	250	250	400	400	400
$\Delta\phi(\text{jet}_1, E_T^{\rm miss})$(rad) $>$	1.5	1.5	1.5	2.5	2.5	2.5
$\min[\Delta\phi(\text{jet}_{1-2}, E_T^{\rm miss})]$ (rad) $<$	2.5	2.5	2.5			
$m_{\rm T2}$(GeV) $>$	100	100	100			
$m_{\rm T2}$(GeV) $<$	400	400	400			
m_{jj}(GeV) $>$	50	50	50			
m_{jj}(GeV) $<$	700	700	700			
$m_T^{\rm min}(\text{jet}_{1-2}, E_T^{\rm miss})$ (GeV) $<$				120	120	120
$m_{\rm eff}$(GeV) $>$				250	250	250
$m_{\rm eff}$(GeV) $<$				350	350	350
$E_T^{\rm miss}/\sqrt{H_T}$(GeV$^{1/2}$) $>$	1	1	1			
$E_T^{\rm miss}/\sqrt{H_T}$(GeV$^{1/2}$) $<$	15	15	13			
H_T(GeV) $<$	115	120	120	155	160	165

The selection criteria used for the single lepton channel

Requirement	$1\ell 2j$		
	$1\ell 2j$-A	$1\ell 2j$-B	$1\ell 2j$-C
N(jets)	≥ 2	≥ 2	≥ 2
$p_T(j_1)$ (GeV) $<$	60	70	80
$p_T(j_2)$ (GeV) $<$	50	50	50
Leading p_T^ℓ (GeV) $>$	10	10	10
Leading p_T^ℓ (GeV) $<$	40	40	40
m_T^ℓ (GeV) $<$	60	60	60
$m_T^{\text{min}}(\text{jet}_{1-2}, E_T^{\text{miss}})$ (GeV) $<$	140	140	140
m_{eff} (GeV) $>$	180	180	180
m_{eff} (GeV) $<$	240	240	240
E_T^{miss}(GeV) $<$	250	250	250
$\Delta\phi(\text{jet}_1, E_T^{\text{miss}})$(rad) $>$	2.5	2.5	2.5
H_T(GeV) $<$	105	105	105

The selection criteria used for the two lepton channel (SFOS and DFOS)

	$2\ell 1j$-SF			$2\ell 1j$-DF		
Requirement	$2\ell 1j$-SF-A	$2\ell 1j$-SF-B	$2\ell 1j$-SF-C	$2\ell 1j$-DF-A	$2\ell 1j$-DF-B	$2\ell 1j$-DF-C
E_T^{miss} (GeV) $<$	150	150	150	150	150	150
m_T^{ℓ} (GeV) $<$	80	80	80	80	80	80
$\Delta\phi(j_1, E_T^{\text{miss}})$ (rad) $>$	2.7	2.7	2.7	2.7	2.7	2.7
$\Delta R_{\ell\ell}$ (rad) $<$	1.0	1.0	1.0	3.0	3.0	3.0
$m_{\ell\ell}$ (GeV) $<$	50	50	50	40	40	40
$E_T^{\text{miss}}/H_T >$	0.7	0.7	0.7	0.7	0.7	0.7
m_{eff} (GeV) $>$	160	160	160	160	160	160
m_{eff} (GeV) $<$	260	270	280	260	270	280

- The neutralino relic density arising from the decay of the gravitino is given by

$$\Omega^{G}_{\chi_1^0} h^2 = \sum_{i=1}^{3} \omega_i\, g_i^2 \left(1 + \frac{m_i^2}{3m_{\tilde{G}}^2}\right) \ln\left(\frac{k_i}{g_i}\right) \left(\frac{m_{\tilde{\chi}_1^0}}{100\,\text{GeV}}\right) \left(\frac{T_R}{10^{10}\,\text{GeV}}\right),$$

where $\omega_i(i = 1, 2, 3) = (0.018, 0.044, 0.177)$ and

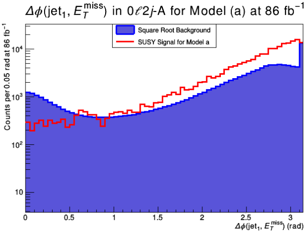
$$\frac{m_i(T_R)}{m_i(M_G)} = \frac{g_i^2(T_R)}{g_i^2(M_G)},$$

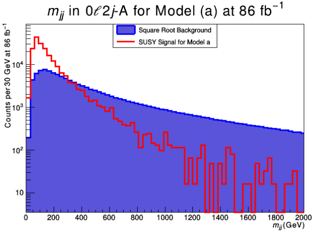
$$\frac{1}{g_i^2(T_R)} = \frac{1}{g_i^2(M_G)} + \frac{\beta_i^{(i)}}{8\pi^2} \ln\left(\frac{M_G}{T_R}\right)$$

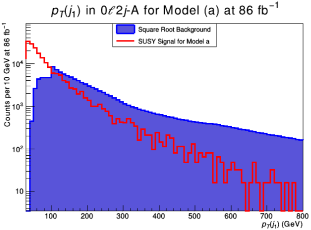
Here M_G is the GUT scale, $g_i(T_R), m_i(T_R)$ are the gauge couplings and the gaugino masses at T_R, and $g_i(M_G), m_i(M_G)$ are their GUT values, $\beta_i^{(1)}$ are the one loop evolution coefficients given by $\beta_i^{(1)}(i = 1, 2, 3) = (11, 1, -3)$

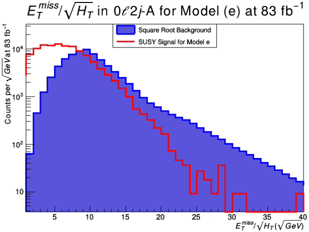
Branching ratios of the leading decay channels, the total two-body decay width and the lifetime of the gravitino for the benchmarks

Model	Br($\tilde{G} \to \tilde{g} g$)	Br($\tilde{G} \to \tilde{\chi}_1^{\pm} W^{\mp}$)	Br($\tilde{G} \to \tilde{\chi}_1^0 \gamma$)	Br($\tilde{G} \to \tilde{\chi}_1^0 Z$)	$\Gamma_{\tilde{G}}^{\text{two-body}} \times 10^{-24}$ (GeV)	Lifetime (s)
(a)	0.598	0.150	0.040	0.035	7.9	0.083
(b)	0.619	0.156	0.060	0.018	10.1	0.065
(c)	0.619	0.155	0.058	0.020	17.0	0.039
(d)	0.620	0.156	0.057	0.021	12.3	0.053
(e)	0.616	0.155	0.044	0.033	5.4	0.121
(f)	0.616	0.155	0.043	0.034	6.6	0.099
(g)	0.614	0.155	0.041	0.036	3.6	0.183
(h)	0.618	0.155	0.038	0.039	14.1	0.047
(i)	0.617	0.155	0.041	0.037	4.4	0.151
(j)	0.617	0.155	0.036	0.042	8.9	0.074


$\Delta\phi(\text{jet}_1, E_T^{\text{miss}})$ in $0\ell 2j$-A for Model (a) at 86 fb^{-1}
Square Root Background
SUSY Signal for Model a
Counts per 0.05 rad at 86 fb^{-1}
$\Delta\phi(\text{jet}_1, E_T^{\text{miss}})$ (rad)


m_{jj} in $0\ell 2j$-A for Model (a) at 86 fb^{-1}
Square Root Background
SUSY Signal for Model a
Counts per 30 GeV at 86 fb^{-1}
m_{jj}(GeV)


$p_T(j_1)$ in $0\ell 2j$-A for Model (a) at 86 fb^{-1}
Square Root Background
SUSY Signal for Model a
Counts per 10 GeV at 86 fb^{-1}
$p_T(j_1)$ (GeV)


$E_T^{miss}/\sqrt{H_T}$ in $0\ell 2j$-A for Model (e) at 83 fb^{-1}
Square Root Background
SUSY Signal for Model e
Counts per $\sqrt{GeV}$ at 83 fb^{-1}
$E_T^{miss}/\sqrt{H_T}(\sqrt{GeV})$

Supersymmetry at a 28 TeV hadron collider: The HE-LHC

The selection criteria used for the single lepton channel

Requirement	SR 1ℓ-comp SR-A	SR 1ℓ-comp SR-B	SR 1ℓ-comp SR-C	SR 1ℓ-$\tilde{g}$ SR-A	SR 1ℓ-$\tilde{g}$ SR-B	SR 1ℓ-$\tilde{g}$ SR-C
$N_{\rm jets} \geq$	2	2	2	2	2	2
$E_T^{\rm miss}$ (GeV) $>$				150	150	150
H_T (GeV)	< 250	< 250	< 250	> 600	> 600	> 600
$E_T^{\rm miss}/\sqrt{H_T}$ (GeV$^{1/2}$) $>$	7	7	7	10	10	10
$m_{\rm eff}$ (GeV)	< 350	< 350	< 350	> 800	> 800	> 800
$R >$	0.6	0.7	0.85	0.7	0.8	0.85
$H_{20} <$				0.5	0.5	0.5
$p_T(j_2)$ (GeV) $>$				110	110	110
$p_T(j_3)$ (GeV) $>$				80	80	80
$p_T(j_4)$ (GeV) $>$				50	50	50
m_T^{ℓ} (GeV) $>$				100	100	100
$m_T^{\rm min}(j_{1-2}, E_T^{\rm miss})$ (GeV) $>$				200	200	200

	2ℓ-SFOS-comp			2ℓ-SFOS-$\tilde{g}$		
Requirement	SR-A	SR-B	SR-C	SR-A	SR-B	SR-C
$N_{\text{jets}} \geq$	2	2	2	2	2	2
E_T^{miss} (GeV)	< 150	< 150	< 150	> 150	> 150	> 150
m_T^{ℓ} (GeV)	< 80	< 80	< 80	> 150	> 180	> 200
$p_T(j_1)$ (GeV)	< 90	< 90	< 90	> 120	> 120	> 120
$p_T(j_2)$ (GeV)	< 48	< 48	< 48	> 80	> 80	> 80
$R >$	0.7	0.7	0.7	0.8	0.8	0.8
$A <$	0.4	0.4	0.4			
$m_{\ell\ell}$ (GeV) $<$	25	25	25		Z-veto	
H_T(GeV)	< 190	< 190	< 190	> 500	> 500	> 500
m_{eff} (GeV) $>$	180	180	180	900	900	900
m_{eff} (GeV) $<$	400	400	400			
$\Delta R_{\ell\ell}$ (rad) $<$	0.4	1.0	2.5			
$M_{T_2}^{\text{dijet}}$ (GeV) $>$				700	700	700
$M_{T_2}^{\text{dilepton}}$ (GeV) $>$				600	600	600

	SR 3ℓ-comp			SR 3ℓ-$\tilde{g}$		
Requirement	SR-A	SR-B	SR-C	SR-A	SR-B	SR-C
$E_T^{\rm miss}$ (GeV) $>$				150	150	150
$m_T^{\rm min}$ (GeV) $>$				100	100	100
$p_T^{\ell\ell\ell}$ (GeV) $<$	60	60	60	150	150	150
$R >$	0.45	0.5	0.55	0.55	0.6	0.65
$m_{\rm eff}$ (GeV)	< 500	< 500	< 500	> 650	> 650	> 650
$M_{T_2}^{\rm dijet}$ (GeV) $>$	200	200	200			

The selection criteria used for the three-lepton signal region. The SR 3ℓ-comp targets soft final states resulting from the electroweakino production and 3ℓ-$\tilde{g}$ targets final states from gluino production. A Z-veto is applied to both SRs.