



Searches for Strongly Produced SUSY Particles including R-parity Violating Decays with ATLAS

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Introduction

- Supersymmetry (SUSY) is one of the most promising extensions of the Standard Model.
 - It can solve the hierarchy problem.
- Strongly interacting SUSY particles (gluinos and squarks) can be produced in large cross sections at the LHC.
- If R-parity $(P_R = (-1)^{3B+L+2s})$ is conserved, the lightest SUSY particle (LSP) becomes stable.
 - LSP is seen as missing momentum in collider.
 - LSP can be dark matter candidate.





Strongly Produced SUSY Searches So Far

 In the searches at √s=13 TeV using ~15 fb⁻¹ so far, no significant excess was seen in analyses targeting strongly produced SUSY assuming R-parity conservation.



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Contents

- More complex final states are searched for R-parity conserving models.
 - 0-lepton+8-10 jets+ E_T^{miss} (18.2 fb⁻¹)
 - <u>ATLAS-CONF-2016-095</u>
 - SFOS (Same-Flavor Opposite-Sign) 2-lepton+jets+E_T^{miss} (14.7 fb⁻¹)
 - arXiv:1611.05791
 - Photon+jets+ E_T^{miss} (13.3 fb⁻¹)
 - <u>ATLAS-CONF-2016-066</u>
- R-parity violation (RPV) scenario is also considered.
 - RPV multijets (14.8 fb⁻¹)
 - <u>ATLAS-CONF-2016-057</u>
 - RPV 1-lepton+multijets (14.8 fb⁻¹)
 - <u>ATLAS-CONF-2016-094</u>

0-lepton+Multijets+E_T^{miss}

- SUSY particles can decay in cascade and produce more particles in final state.
 - Each particle become soft.
- Event selection

- <u>ATLAS-CONF-2016-095</u>



Signal region	8j50	9j50	10j50		
$R = 0.4$ jet $ \eta $		< 2.0 for all	SRs		
$R = 0.4$ jet $p_{\rm T}$	> 50 GeV for all SRs				
N _{jet}	≥8	≥9	≥10		
$M_{ m J}^{\Sigma}$	> 340 GeV or > 500 GeV				
$E_{\rm T}^{\rm miss}/\sqrt{H_{\rm T}}$	$> 4 \mathrm{GeV}^{1/2}$ for all SRs				

$$M_{\rm J}^{\Sigma} = \sum_j m_j^{R=1.0}$$

Reclustered jet mass with R=1.0 using anti- k_t R=0.4 jets as input

Background Estimation

- Leptonic background ($t\bar{t}$, W+jets):
 - MC simulation is normalized in 1-lepton control region.
- Multijet background
 - Measure $E_T^{miss}/\sqrt{H_T}$ shape in 6-jet region.
 - 7-jet region is for validation.





Interpretation

Results are interpreted in pMSSM and simplified models.



SFOS 2-lepton+Jets+ E_{T}^{miss}

- Small excesses have been seen in SFOS 2-lepton+jets+ E_T^{miss} searches.
 - They need to be investigated in $\sqrt{s}=13$ TeV with higher statistics.

Local significance observed in each analysis

ATLAS (EJPC75(2015)318, ATLAS-CONF-2015-082)				<u>-082</u>) (CMS (JH	EP04(2015	5)124,CMS-PAS-S	SUS-16-02	1)	q q q	
On-shell Z	≥V, 3.2 fb ⁻¹) ≥V, 20 fb ⁻¹)			No excess (13 TeV, 12.9 fb ⁻¹) No excess (8 TeV, 19.4 fb ⁻¹)			<i>p</i> <i>g</i>	$\tilde{\chi}_2^0$			
m _{II} "edge"			_			2.0 σ (13 TeV, 12.9 fb ⁻¹)				χ_1^2	
	No exce	ess (8 TeV, 20 fb ⁻¹))	2.4 σ (8 TeV, 19.4 fb ⁻¹)			P	$\sim q q q^{Z^{(*)}}$		
 Event selection arXiv:1611.05791 		-	On-she regions	11 Z	E ^{miss} [GeV]	H ^{incl} [GeV]	<i>n</i> jets	<i>m_{ℓℓ}</i> [GeV]	S	SF/DF Δø(jet ₁	$(2, p_{\mathrm{T}}^{\mathrm{miss}})$
		-	Signal r	region							
		-	SRZ		> 225	> 600	≥ 2	$81 < m_{\ell\ell} < 1$	01	SF >	0.4
m, is segme	ented	Edge regions		E _T ^{miss} [GeV]	H _T [GeV]	<i>n</i> _{jets}	<i>m_{ℓℓ}</i> [GeV]	SF/DF	OS/SS	$\Delta \phi(\text{jet}_{12}, p_{\text{T}}^{\text{miss}})$	$m_{\ell\ell}$ ranges
in multi-bins	s for	Signal re	egions								
"odgo" opol	voio	SR-low		> 200	_	≥ 2	> 12	SF	OS	> 0.4	9
euge anai	ysis.	SR-med	ium	> 200	> 400	≥ 2	> 12	SF	OS	> 0.4	8
		SR-high		> 200	> 700	≥ 2	> 12	SF	OS	> 0.4	7

Background Estimation

- Flavor symmetric background ($t\bar{t}$, WW):
 - Estimated from Different-flavor (DF) OS 2-lepton data events correcting ee,µµ/eµ acceptance
 - Cross-checked by m_{\parallel} side-band estimation for on-shell Z SR.
- Z/γ*+jets background:
 - E_T^{miss} distribution is estimated from γ +jets events.
 - Photon p_T is smeared according to
 - $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ resolution.
 - m_{II} shape is extracted from MC simulation.
- Fake lepton background (W+jets):
 - Estimated by the events passing loose-lepton ID to tight-lepton ID.

$$N_{\text{pass}}^{\text{fake}} = \frac{N_{\text{fail}} - (1/\epsilon^{\text{real}} - 1) \times N_{\text{pass}}}{1/\epsilon^{\text{fake}} - 1/\epsilon^{\text{real}}}$$



Results

• On-shell Z

	SRZ	SRZ ee	SRZ $\mu\mu$
Observed events	60	35	25
Total expected background events	53.5 ± 9.3	27.1 ± 5.1	26.8 ± 4.4
Flavour-symmetric ($t\bar{t}$, Wt , WW and $Z \rightarrow \tau\tau$) events	33.2 ± 3.9	16.5 ± 2.1	16.7 ± 2.0
Z/γ^* + jets events	3.1 ± 2.8	$1.0^{+1.3}_{-1.0}$	2.1 ± 1.4
WZ/ZZ events	14.2 ± 7.7	7.8 ± 4.3	6.4 ± 3.5
Rare top events	2.9 ± 0.8	1.4 ± 0.4	1.5 ± 0.4
Fake-lepton events	$0.1^{+0.8}_{-0.1}$	$0.5^{+0.7}_{-0.5}$	$0^{+0.2}$
p(s=0)	0.32	0.15	0.5
Significance (σ)	0.47	1.02	0
Observed (Expected) S^{95}	$28.2(24.5^{+8.9}_{-6.7})$	$22.0(15.8^{+6.5}_{-4.5})$	$12.9(14.0^{+5.7}_{-3.9})$
$\langle \epsilon \sigma \rangle_{\rm obs}^{95}$ [fb]	1.9	1.5	0.88



• m_{II} edge





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Interpretation

 No significant excess is seen in any of the SRs, this result is used to set limits on models.





Photon+Jets+ E_T^{miss}

- In Gauge Mediated Supersymmetry Breaking (GMSB) models, a photon can be expected in the final state as well as Z or Higgs boson depending on component of NLSP.
- Event selection

ATLAS-CONF-2016-066

	SRL	SR _H
N _{photons}	> 0	> 0
$p_{\rm T}^{\rm leading-\gamma}$	> 145 GeV	> 400 GeV
N _{leptons}	0	0
N _{jets}	> 4	> 2
$\Delta \phi$ (jet, $E_{\rm T}^{\rm miss}$)	> 0.4	> 0.4
$\Delta \phi(\gamma, E_{\rm T}^{\rm miss})$	> 0.4	> 0.4
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 200 GeV	> 400 GeV
$m_{\rm eff}$	> 2000 GeV	> 2000 GeV
R_{T}^4	< 0.90	-



Background component

- Wγ, *tt*γ
- Fake photon from a jet
- Fake photon from an electron

$$R_{\rm T}^4 = \frac{\sum_{i=1}^4 p_{\rm T}^i}{\sum_{\rm jets} p_{\rm T}^j}$$

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Results and Interpretation



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RPV 1-lepton+Multijets

 If RPV is allowed, LSP is not stable anymore and no E_T^{miss} from SUSY particles.

 $W_{\mathcal{R}_{P}} = \frac{1}{2}\lambda_{ijk}L_{i}L_{j}\bar{E}_{k} + \lambda'_{ijk}L_{i}Q_{j}\bar{D}_{k} + \frac{1}{2}\lambda''_{ijk}\bar{U}_{i}\bar{D}_{j}\bar{D}_{k} + \kappa_{i}L_{i}H_{2}$

• If there are many particles in final state from cascade decay and RPV decays of SUSY particles, signal events can be distinguished from SM background.



Event Selection

• Two searches are preformed for RPV models in multi-object final states.

RPV Multijets

ATLAS-CONF-2016-057

Event selection

- N_{jets}≥4 or 5 with R=1.0, p_T>200 GeV, |η|<2.0
- N_{b-jets}≥0 or 1 with R=0.4, p_T>50 GeV, |η|<2.5
- |Δη₁₂|<1.4 for leading 2 R=1.0 jets
- M_J^Σ=Σ_{R=1.0}⁴m^{jet}>0.8 TeV (N_{jet}≥4) or 0.6 TeV (N_{jet}≥5)

RPV 1-lepton+multijets

ATLAS-CONF-2016-094

Event selection

- at least 1-lepton
- 2D bins of

 $N_{jets} = [5, 6, 7, 8, 9, \ge 10]$ $N_{b-jets} = [0, 1, 2, 3, \ge 4]$ with $p_T > 40$ GeV or 60 GeV

Background Estimation for RPV Multijets

- Jet mass template is obtained from control regions as a function of jet p_T and η.
 - Soft jets with 100 GeV<p_T<200 GeV are used in CRs.

M	b-t	tag	b-veto	inclusive		
Ivjet	$ \Delta\eta_{12} >1.4$	$ \Delta\eta_{12} <1.4$	-	$ \Delta\eta_{12} >1.4$	$ \Delta\eta_{12} <1.4$	
= 3	3jCRb1_4j	-	3jCRb0_4j	3jCl	R_5j	
≥ 4	4jVRb1	4jSRb1	-	4jVR	4jSR	
≥ 5	5jVRb1	5jSRb1	-	5jVR	5jSR	

Background estimation is validated in the region with $|\Delta\eta_{12}|>1.4$





Result and Interpretation

Result is interpreted in RPV models.

$4jSRb1 > 0.8 TeV$ 46 $61 \pm 10 \pm 6 \pm 12$	
4jSR 122 $151 \pm 15 \pm 17 \pm 20$	0
5jSRb1 30 $18.2 \pm 4.2 \pm 2.5 \pm 3$	0.
5jSR 50.0 Iev 64 $51.4 \pm 7.7 \pm 7.2 \pm 6$	5.5



5jet signal region



Background Estimation for RPV 1-lepton+Multijets

- W/Z+jets
 - b-jet multiplicity spectra is from simulation
 - Jet multiplicity spectra is from data assuming

 $r = N_{j+1}^{W/Z+jets} / N_j^{W/Z+jets}$ is constant. Then,

$$N_{j,b}^{W/Z+jets} = \frac{\mathrm{MC}_{j,b}^{W/Z+jets}}{\mathrm{MC}_{j}^{W/Z+jets}} \cdot k^{W/Z+jets} \cdot \mathrm{MC}_{5}^{W/Z+jets} \cdot r^{(j-5)}$$

- $t\overline{t}$ +jets
 - b-jet multiplicity spectra is obtained from low jet multiplicity data $N_{i,b}^{t\bar{t}+jets} = N_i^{t\bar{t}+jets} \cdot f_{j,b}$



$$f_{(j+1),b} = f_{j,b} \cdot x_0 + f_{j,(b-1)} \cdot x_1 + f_{j,(b-2)} \cdot x_2$$

additional jet is not b-tagged (x_0) , b-tagged (x_1) , b-tagged and another jet is b-tagged (x_2)

• Background is normalized to match data separately in each N_i slice.

Result and Interpretation



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Conclusion

- Extended searches for strongly produced SUSY particles including Rparity violation have been performed in ATLAS using Run 2 dataset up to 18 fb⁻¹.
- Still no significant excess from SM prediction is seen.
- We expect to provide new results with $\sim 36 \text{ fb}^{-1}$ soon, please stay tuned!





Backup

Systematic Uncertainties on SFOS Search

 Overview of dominant systematic uncertainties for SFOS 2-lepton+Jets+ETmiss search.

Source	Relative systematic uncertainty [%]			
	SRZ	SR-low	SR-medium	SR-high
Total systematic uncertainty	17	8-30	6–34	10–45
WZ/ZZ generator uncertainty	13	0–7	0-6	0-10
Flavour symmetry (statistical)	7	3-16	5-16	7–28
WZ/ZZ scale uncertainty	6	0-1	0-1	0-2
Z/γ^* + jets (systematic)	4	0-15	0-25	0-15
Flavour symmetry (systematic)	3	2-23	2-15	4-25
Z/γ^* + jets (statistical)	2	0-3	0-5	0-1
Fake leptons	1	0–17	2-18	2–20

m_{ll} Edge Analysis Comparison

• Comparison of m_{II} edge analysis between ATLAS and CMS at Run2.

	ATLAS	CMS
N _{jet}	<u>></u> 2 (p _T >30 GeV)	<u>></u> 2 (p _T >35 GeV)
p _T (lepton)	>25,10 GeV	>25,20 GeV
m _{II}	>12 GeV (binned)	>20 GeV (unbinned)
E_{T}^{miss}	>200 GeV	>150 GeV
Η _T	>0(,400,700) GeV	
ttbar selection		NLL



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SFOS 2-lepton m_{ll} Edge

Signal region distributions



Interpretations in Squark Production

Exclusion limits on squark-pair production models



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Summary of SUSY Searches at ATLAS

ATLAS SUSY Searches* - 95% CL Lower Limits

St	atus: August 2016							$\sqrt{s} = 7, 8, 13 \text{ TeV}$
	Model	ε, μ, τ, γ	⁄Jets	E ^{mbs}	∫£dı[fi	-1] Mass limit	$\sqrt{s} = 7, 8 \text{ TeV}$ $\sqrt{s} = 13 \text{ TeV}$	Reference
Indusive Searches	$\begin{array}{l} \text{MSUGRACMSSM} \\ \begin{array}{c} \tilde{q}_{1}, \tilde{q}_{1} \rightarrow q F_{1}^{0} \\ \tilde{q}_{2}, \tilde{q}_{2} \rightarrow q F_{1}^{0} \\ (\text{compressed}) \\ \tilde{z}_{2}, \tilde{z}_{3} \rightarrow q F_{1}^{0} \\ \tilde{z}_{3}, \tilde{z}_{3} \rightarrow q F_{1}^{0} \rightarrow q q W^{+} F_{1}^{0} \\ \tilde{z}_{3}, \tilde{z}_{3} \rightarrow q q W^{+} F_{1}^{0} \\ \tilde{G}M \\ \tilde{y}_{3}, \tilde{z}_{3} \rightarrow q W^{+} F_{1}^{0} \\ \tilde{g}_{3}, \tilde{z}_{3} \rightarrow q W^{+} F_{1}^{0} \\ \tilde{g}_{3}, \tilde{z}_{3} \rightarrow q q W^{+} F_{1}^{0} \\ \tilde{g}_{3}, \tilde$	$\begin{array}{c} 0.3 \ e, \mu/1.2 \ r\\ 0\\ monojet\\ 0\\ 0\\ 3 \ e, \mu\\ 2 \ e, \mu(SS)\\ 1.2 \ r + 0.1\\ 2 \ \gamma\\ \gamma\\ \gamma\\ 2 \ e, \mu(Z)\\ 0\\ \end{array}$	2-10 jets/3 k 2-6 jets 1-3 jets 2-6 jets 2-6 jets 2-6 jets 0-3 jets ℓ 0-2 jets 1 k 2 jets 2 jets mono-jet	Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 13.3 13.3 13.3 13.2 13.2 3.2 20.3 13.3 20.3 20.3	6. 8 6 6 6 7 608 GeV 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 800 GeV 8 800 GeV	$\begin{array}{cccc} \textbf{1.85 TeV} & m \ell =m \ell\rangle \\ \textbf{1.35 TeV} & m \ell_1^{-1}\rangle<200\text{GeV}, rm(1^{-4}\text{gen.4})=rm 2^{-4}\text{gen.4}) \\ m \ell_1^{-1}\rangle<26\text{GeV} \\ \textbf{1.80 TeV} & m \ell_1^{-1}\rangle<26\text{GeV} \\ \textbf{1.83 TeV} & m \ell_1^{-1}\rangle<400\text{GeV} \\ \textbf{1.87 TeV} & m \ell_1^{-1}\rangle<400\text{GeV} \\ \textbf{1.7 TeV} & m \ell_1^{-1}\rangle<400\text{GeV} \\ \textbf{1.7 TeV} & m \ell_1^{-1}\rangle<400\text{GeV} \\ \textbf{1.0 TeV} & m \ell_1^{-1}\rangle$	1507.05525 ATLAS.CONF-2016.078 1604.07773 ATLAS.CONF-2016.078 ATLAS.CONF-2016.078 ATLAS.CONF-2016.037 ATLAS.CONF-2016.037 1606.00150 1507.05493 ATLAS.CONF-2016.098 1502.05493 ATLAS.CONF-2016.098
3 rd gen. <u>§</u> med.	<u>ĝ</u> ĝ, ĝ→kĥξ ⁰ ĝĝ, ĝ→utξ ⁰ ĝĝ, ĝ→kiξ ¹	0 0-1 e. µ 0-1 e. µ	3 b 3 b	Yes Yes Yes	14.8 14.8 20.1	2 2 2	1.99 TeV m k ² ₁)=0 GeV 1.99 TeV m k ² ₁)=0 GeV 1.37 TeV m k ² ₁)<300 GeV	ATLAS-CONF-2016-052 ATLAS-CONF-2016-052 1407-0600
3 rd gen: squarks direct production	$\begin{array}{l} k_{1}k_{1}, k_{1} \rightarrow b \tilde{\xi}_{1}^{0} \\ \bar{h}_{1}\bar{h}_{1}, \bar{h}_{1} \rightarrow \tilde{\xi}_{1}^{0} \\ \bar{h}_{2}\bar{h}_{2}, \bar{h}_{2} \rightarrow \tilde{h}_{1} + Z \\ \bar{h}_{2}\bar{h}_{2}, \bar{h}_{2} \rightarrow \tilde{h}_{1} + Z \\ \bar{h}_{2}\bar{h}_{2}, \bar{h}_{2} \rightarrow \tilde{h}_{1} + k \end{array}$	0 $2 e, \mu$ (SS) $0.2 e, \mu$ $0.2 e, \mu$ 0 $2 e, \mu (Z)$ $3 e, \mu (Z)$ $1 e, \mu$	2 <i>b</i> 1 <i>b</i> 1-2 <i>b</i> 0-2 jets/1-2 <i>k</i> mono-jet 1 <i>b</i> 1 <i>b</i> 5 jets + 2 <i>b</i>	Yes Yes 4. Yes 4. Yes Yes Yes Yes	3.2 13.2 7/13.3 7/13.3 3.2 20.3 13.3 20.3	Å. 940 GeV Å. 325-635 GeV ĝ1 17-170 GeV 200-720 GeV Å. 90-198 GeV Å. 90-323 GeV Å. 90-323 GeV Å. 90-302 GeV Å. 320-600 GeV Å. 320-620 GeV	$\begin{split} m[\hat{c}_1^n] < 100 GeV \\ m[\hat{c}_1^n] < 100 GeV, m[\hat{c}_1^n] &= m(\hat{c}_1^n) + 100 GeV \\ m[\hat{c}_1^n] &= 2m(\hat{c}_1^n), m[\hat{c}_1^n] &= 56 GeV \\ m[\hat{c}_1^n] &= 10 GeV \\ m[\hat{c}_1^n] &= 10 GeV \\ m[\hat{c}_1^n] &= 10 GeV \\ m[\hat{c}_1^n] &= 100 GeV \\ m[\hat{c}_1^n] &= 100 GeV \\ m[\hat{c}_1^n] &= 100 GeV \end{split}$	1606.08772 ATLAS-CONF-2016-037 1200.2102, ATLAS-CONF-2016-077 1506.09816, ATLAS-CONF-2016-077 1604.07773 1403.5222 ATLAS-CONF-2016-038 1506.08816
EW direct	$\begin{array}{l} \tilde{\ell}_{LL}\tilde{\ell}_{L,R}, \tilde{\ell} \! \rightarrow \! \ell R^{2}_{1} \\ \tilde{\ell}_{LL}^{-1} \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \\ \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \\ \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \\ \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \\ \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \\ \tilde{\ell}_{L}^{-1} \tilde{\ell}_{L}^{-1} \\ \tilde{\ell}_{L}^{-1} $	$2e, \mu$ $2e, \mu$ 2τ $3e, \mu$ $2\cdot 3e, \mu$ $2\cdot 3e, \mu$ $7\tau/\gamma\gamma = e, \mu, \gamma$ $4e, \mu$ $4e, \mu + \gamma$ $2\cdot \gamma$	0 - 0-2 jets 0-2 j. 0-2 j. 0 -	Yes Yes Yes Yes Yes Yes Yes	20.3 13.3 14.8 13.3 20.3 20.3 20.3 20.3 20.3 20.3	Ž 90-335 GeV Šrij 640 GeV Šrij 580 GeV Šrij, Šrij 1.0 TeV Šrij, Šrij 425 GeV Šrij, Šrij 035 GeV Šrij, Šrij 035 GeV W 115-370 GeV W 590 GeV	$\begin{split} m[\tilde{c}_{1}^{n}] &= 0 G_{eV} \\ m[\tilde{c}_{1}^{n}] &= 0 G_{eV} (m[\tilde{c}_{1}^{n}]) &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= 0 G_{eV} (m[\tilde{c}_{1}^{n}]) &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{2}^{n}] , m[\tilde{c}_{1}^{n}] &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] , m[\tilde{c}_{1}^{n}] &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] , m[\tilde{c}_{1}^{n}] &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] , m[\tilde{c}_{1}^{n}] &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] , m[\tilde{c}_{1}^{n}] &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] , m[\tilde{c}_{1}^{n}] &= 0 S[m[\tilde{c}_{1}^{n}]) \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] \\ m[\tilde{c}_{1}^{n}] \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] \\ m[\tilde{c}_{1}^{n}] &= m[\tilde{c}_{1}^{n}] \\ m[\tilde{c}_{1}$	1403 5294 ATLAS-CONF-2016-095 ATLAS-CONF-2016-095 ATLAS-CONF-2016-096 1403-5294,1402-7029 1501.07110 1405-5086 1507.06493 1507.06493
Long-lived particles	$\begin{array}{l} \operatorname{Direct} \{\xi_1^*, \xi_1^* \ {\rm prod., \ \rm long-lived.} \\ \operatorname{Direct} \{\xi_1^*, \xi_1^* \ {\rm prod., \ \rm long-lived.} \\ \operatorname{Stable, \ } \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{H-hadron} \\ \operatorname{Stable, \ } \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{H-hadron} \\ \operatorname{Stable, \ } \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{H-hadron} \\ \operatorname{SMSB}, \ {}_{\mathcal{S}}^* \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{H-hadron} \\ \operatorname{SMSB}, \ {}_{\mathcal{S}}^* \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{H-hadron} \\ \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{H-hadron} \\ \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{H-hadron} \\ \operatorname{Speed} \ {}_{\mathcal{S}}^* \operatorname{Speed} \ {}_{S$	$ \begin{array}{ccc} & \mathbb{P}_1^+ & \mathbb{D} \text{is app. trk} \\ & \mathbb{P}_1^+ & \mathrm{d} \mathbb{E}/\mathrm{d} x \mathrm{trk} \\ & 0 \\ & \mathrm{trk} \\ & \mathrm{d} \mathbb{E}/\mathrm{d} x \mathrm{trk} \\ & \mathrm{d} \mathbb{E}/\mathrm{d} x \mathrm{trk} \\ & \mathbb{P}(x,\mu) & 1-2\mu \\ & 2\gamma \\ & \mathrm{d} \text{is pl. } x x/ x \mu / \mu \\ & \mathrm{d} \text{is pl. } x \mathrm{tx} + \mathrm{je} \end{array} $	1 jet - 1-5 jets - - - - - - - - - - - - - - - - - - -	Yes Yes · · Yes · Yes	20.3 18.4 27.9 3.2 19.1 20.3 20.3 20.3	x- x- x- 270 GeV x- x- 495 GeV x- 850 GeV x- 537 GeV x- 537 GeV x- 440 GeV x- 1.0 TeV x- 1.0 TeV	$\begin{array}{c} m \ell_1^2\rangle+m(\ell_1^2)-160~{\rm MeV}, \pi(\ell_1^2)=0.2~{\rm nn}\\ m \ell_1^2\rangle+m(\ell_1^2)-160~{\rm MeV}, \pi(\ell_1^2)=15~{\rm nn}\\ m \ell_1^2\rangle=100~{\rm GeV}, 10{\rm pasc}, \pi(\varrho)<1000~{\rm n}\\ 1.57~{\rm TeV}\\ 1.57~{\rm TeV}\\ 1.67~{\rm teV}\\ 1.67~{\rm teV}, 3.63~{\rm teV}, 1.57~{\rm 10~nn}\\ 1.67~{\rm teV}, 3.63~{\rm teV}, 1.57~{\rm teV}\\ 1.67~{\rm teV}\\ 1.67~{\rm teV}\\ 1.67~{\rm teV}, 1.57~{\rm teV}\\ 1.67~{\rm teV}\\ $	1310.3875 1508.06332 1310.6584 1608.05120 1604.04220 1411.6705 1409.5542 1504.05162 1504.05162
NdB	$\begin{split} & LFV_{pp} \rightarrow \mathfrak{d}_r + \mathfrak{X}, \mathfrak{d}_r \rightarrow \mathfrak{s}\mu/\mathfrak{e}\tau/\mathfrak{e}\tau/\mathfrak{e}\tau\\ & Bilnear \; FPV \; CMSSM \\ & \mathcal{K}_1^r \mathcal{K}_1, \mathcal{K}_1^r \rightarrow \mathcal{K}_2^r \mathcal{K}$	$r = e\mu_e r_e \mu_e r_e \mu_e r_e r_e \mu_e SS)$ $2 e, \mu (SS)$ $\mu\mu\nu = 4 e, \mu = 0$ $4 e, \mu = 0$ $4 e, \mu = 0$ $1 e, \mu = 0$ $1 e, \mu = 0$ $2 e, \mu$	0-3 b - 1-5 large- R jet 1-5 large- R jet 8-10 jets/0-4 8-10 jets/0-4 2 jets + 2 b 2 b	- Yes Yes ts - ts - ts -	3.2 20.3 13.3 20.3 14.8 14.8 14.8 14.8 15.4 20.3	\$\vec{v}_s\$ 1.14'' \$\vec{k}_1^*\$ 450 GeV 1.14'' \$\vec{k}_1^*\$ 1.08 Te 1.08 Te \$\vec{k}_1^*\$ 1.08 Te 1.08 Te \$\vec{k}_1^*\$ 1.08 Te 1.08 Te \$\vec{k}_1^*\$ 410 GeV 450-510 GeV \$\vec{k}_1^*\$ 0.4-1.0 TeV 0.4-1.0 TeV	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	1607.08079 1404.2500 ATLAS-CONF-2018-075 1405.5086 ATLAS-CONF-2018-057 ATLAS-CONF-2018-057 ATLAS-CONF-2018-094 ATLAS-CONF-2018-094 ATLAS-CONF-2018-094 ATLAS-CONF-2018-024 ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{\epsilon} \rightarrow \epsilon \tilde{\chi}_1^0$	0	2 c	Yes	20.3	a 510 GeV	m(k ⁿ ₁)<200 GeV	1501.01325
	*Only a selection of th	ne available n	nass limits	on nev	× 1	0 ⁻¹	1 Mass scale [TeV]	-

states or phenomena is shown.

Mass scale [TeV]

ATLAS Preliminary

Long-lived Gluino Limits

