# Inclusive searches for squarks and gluinos with the ATLAS detector



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### SUPERSYMMETRY IN ATLAS

#### ATLAS SUSY Searches\* - 95% CL Lower Limits

Status: EPS 2013

ATLAS Preliminary

 $\int \mathcal{L} dt = (4.4 - 22.9) \text{ fb}^{-1}$   $\sqrt{s} = 7, 8 \text{ TeV}$ 

Model	e, μ, τ, γ	Jets	$\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$	∫£ dt[ft	b <sup>-1</sup> ] Mass limit		Reference
$\begin{array}{c} \text{MSUGRA/CMSSM} \\ \text{MSUGRA/CMSSM} \\ \text{MSUGRA/CMSSM} \\ \text{MSUGRA/CMSSM} \\ \tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q \bar{q} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q \bar{q} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q q \tilde{\chi}_{1}^{1} \rightarrow q g W^{\pm} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g} \rightarrow q q q \ell \ell (\ell l) \tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g} \rightarrow q q q \ell \ell (\ell l) \tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0} \\ \text{GMSB} (\tilde{\ell} \text{ NLSP}) \\ \text{GMSB} (\tilde{\ell} \text{ NLSP}) \\ \text{GGM (bino NLSP)} \\ \text{GGM (bino NLSP)} \\ \text{GGM (higgsino-bino NLSP)} \\ \text{GGM (higgsino NLSP)} \\ \text{Gravitino LSP} \end{array}$	$\begin{matrix} 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 0 \\ 1 \ e, \mu \\ 2 \ e, \mu \\ (SS) \\ 2 \ e, \mu \\ 1-2 \ \tau \\ 2 \ \gamma \\ 1 \ e, \mu + \gamma \\ \gamma \\ 2 \ e, \mu \\ (Z) \\ 0 \end{matrix}$	2-6 jets 3-6 jets 7-10 jets 2-6 jets 3-6 jets 3-6 jets 3-6 jets 3-24 jets 0-2 jets 0 1 b 0-3 jets mono-jet	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.7 4.7 20.7 4.8 4.8 4.8 5.8 10.5	q.ğ       1.1 T + 1 + 1 + 1 + 1         ğ.ğ       1.2 TeV         ğ       1.1 TeV         ğ       740 GeV         ğ       1.1 TeV         ğ       1.2 TeV         ğ       1.2 TeV         ğ       1.1 TeV         ğ       1.2 TeV         ğ       900 GeV         ğ       619 GeV         ğ       690 GeV         F <sup>1/2</sup> scale       645 GeV	<b>1.7 TeV</b> $m(\tilde{q})=m(\tilde{g})$ <b>a</b> ny $m(\tilde{q})$ any $m(\tilde{q})$ $m(\tilde{\chi}_{1}^{0})=0$ GeV <b>eV</b> $m(\tilde{\chi}_{1}^{0})=0$ GeV $m(\tilde{\chi}_{1}^{0})=0$ GeV $m(\tilde{\chi}_{1}^{0})<200$ GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}_{1}^{0})+m(\tilde{g}))$ $m(\tilde{\chi}_{1}^{0})<650$ GeV $\tan\beta < 15$ <b>TeV</b> $\tan\beta > 18$ $m(\tilde{\chi}_{1}^{0})>50$ GeV $m(\tilde{\chi}_{1}^{0})>50$ GeV $m(\tilde{\chi}_{1}^{0})>220$ GeV $m(\tilde{\chi}_{1}^{0})>200$ GeV $m(\tilde{\chi}_{1})>200$ GeV $m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2013-047 ATLAS-CONF-2013-062 ATLAS-CONF-2013-062 ATLAS-CONF-2013-054 ATLAS-CONF-2013-047 ATLAS-CONF-2013-062 ATLAS-CONF-2013-062 ATLAS-CONF-2013-026 1209.0753 ATLAS-CONF-2012-144 1211.1167 ATLAS-CONF-2012-152 ATLAS-CONF-2012-147
$\begin{array}{c} \tilde{g} \rightarrow b \bar{b} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow b \bar{t} \tilde{\chi}_{1}^{+} \end{array}$	0 0 0-1 e,μ 0-1 e,μ	3 b 7-10 jets 3 b 3 b	Yes Yes Yes Yes	20.1 20.3 20.1 20.1	ğ         1.2 TeV           ğ         1.14 TeV           ğ         1.34 TeV           ğ         1.34 TeV	$ \begin{array}{ccc} & m(\tilde{\chi}_1^0) <\!\!\! 600  {\rm GeV} \\ & m(\tilde{\chi}_1^0) <\!\!\! 200  {\rm GeV} \\ \hline {\rm TeV} & m(\tilde{\chi}_1^0) <\!\!\! 400  {\rm GeV} \\ \hline {\rm eV} & m(\tilde{\chi}_1^0) <\!\!\! 300  {\rm GeV} \end{array} $	ATLAS-CONF-2013-061 ATLAS-CONF-2013-054 ATLAS-CONF-2013-061 ATLAS-CONF-2013-061
$ \begin{array}{c} \tilde{b}_{1}\tilde{b}_{1}, \tilde{b}_{1} \rightarrow \tilde{b}_{1}^{\tilde{\chi}_{1}^{0}} \\ \tilde{b}_{1}\tilde{b}_{1}, \tilde{b}_{1} \rightarrow t\tilde{\chi}_{1}^{0} \\ \tilde{b}_{1}\tilde{b}_{1}, \tilde{b}_{1} \rightarrow t\tilde{\chi}_{1}^{0} \\ \tilde{t}_{1}\tilde{t}_{1}(\text{light}), \tilde{t}_{1} \rightarrow b\tilde{\chi}_{1}^{1} \\ \tilde{t}_{1}\tilde{t}_{1}(\text{light}), \tilde{t}_{1} \rightarrow Wb\tilde{\chi}_{1}^{0} \\ \tilde{t}_{1}\tilde{t}_{1}(\text{medium}), \tilde{t}_{1} \rightarrow t\tilde{\chi}_{1}^{0} \\ \tilde{t}_{1}\tilde{t}_{1}(\text{medium}), \tilde{t}_{1} \rightarrow t\tilde{\chi}_{1}^{0} \\ \tilde{t}_{1}\tilde{t}_{1}(\text{heavy}), \tilde{t}_{1} \rightarrow t\tilde{\chi}_{1}^{0} \\ \tilde{t}_{1}\tilde{t}_{1}(\text{natural GMSB}) \\ \tilde{t}_{2}\tilde{t}_{2}, \tilde{t}_{2} \rightarrow \tilde{t}_{1} + Z \end{array} \right. $	$\begin{matrix} 0 \\ 2 \ e, \mu \ (SS) \\ 1-2 \ e, \mu \\ 2 \ e, \mu \\ 2 \ e, \mu \\ 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 1 \ e, \mu \\ 0 \\ 3 \ e, \mu \ (Z) \end{matrix}$	2 b 0-3 b 1-2 b 0-2 jets 2 jets 2 b 1 b 2 b nono-jet/c-ta 1 b 1 b	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.1 20.7 4.7 20.3 20.3 20.1 20.7 20.5 20.3 20.7 20.7	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c} & m(\tilde{\chi}_{1}^{0}){<}100GeV \\ & m(\tilde{\chi}_{1}^{0}){=}2m(\tilde{\chi}_{1}^{0}) \\ & m(\tilde{\chi}_{1}^{0}){=}55GeV \\ & m(\tilde{\chi}_{1}^{0}){=}55GeV \\ & m(\tilde{\chi}_{1}^{0}){=}0GeV \\ & m(\tilde{\chi}_{1}^{0}){=}150GeV \\ & m(\tilde{\chi}_{1}^{0}){>}150GeV \\ & m(\tilde{\chi}_{1}){=}m(\tilde{\chi}_{1}^{0}){+}180GeV \end{array}$	ATLAS-CONF-2013-053 ATLAS-CONF-2013-007 1208.4305, 1209.2102 ATLAS-CONF-2013-048 ATLAS-CONF-2013-065 ATLAS-CONF-2013-053 ATLAS-CONF-2013-037 ATLAS-CONF-2013-024 ATLAS-CONF-2013-025 ATLAS-CONF-2013-025
$ \begin{array}{c} \overbrace{\mathbf{N}}_{\mathbf{U}} \overbrace{\mathbf{V}}_{\mathbf{U}} \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}} \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}}, \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}} \rightarrow \widetilde{\ell} \overbrace{\mathbf{V}}_{1}^{\tilde{\ell}} \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}}, \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}} \rightarrow \widetilde{\ell} v(\ell \widetilde{v}) \\ \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}} \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}}, \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}} \rightarrow \widetilde{\tau} v(\tau \widetilde{v}) \\ \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}} \overbrace{\mathbf{X}}_{2}^{O} \rightarrow \widetilde{\ell}_{L} v \widetilde{\ell}_{L} \ell(\widetilde{v}v), \ell \widetilde{v} \widetilde{\ell}_{L} \ell(\widetilde{v}v) \\ \overbrace{\mathbf{X}}_{1}^{\tilde{\ell}} \overbrace{\mathbf{X}}_{2}^{O} \rightarrow W^{*} \widetilde{\chi}_{1}^{O} Z^{*} \overbrace{\mathbf{X}}_{1}^{O} \end{array}\right) $	2 e, μ 2 e, μ 2 τ 3 e, μ 3 e, μ	0 0 0 0 0	Yes Yes Yes Yes Yes	20.3 20.3 20.7 20.7 20.7	$ \begin{array}{c c c c c c c c } \tilde{\ell} & & & & & & & & & & & & & & & & & & &$	$\begin{split} & m(\tilde{\chi}_{1}^{0}) {=} 0 \ GeV \\ & m(\tilde{\chi}_{1}^{0}) {=} 0 \ GeV, \ m(\tilde{\ell}, \tilde{\nu}) {=} 0.5 (m(\tilde{\chi}_{1}^{+}) {+} m(\tilde{\chi}_{1}^{0})) \\ & m(\tilde{\chi}_{1}^{0}) {=} 0 \ GeV, \ m(\tilde{\tau}, \tilde{\nu}) {=} 0.5 (m(\tilde{\chi}_{1}^{+}) {+} m(\tilde{\chi}_{1}^{0})) \\ & m(\tilde{\chi}_{1}^{+}) {=} m(\tilde{\chi}_{2}^{0}), \ m(\tilde{\ell}, \tilde{\nu}) {=} 0.5 (m(\tilde{\chi}_{1}^{+}) {+} m(\tilde{\chi}_{1}^{0})) \\ & m(\tilde{\chi}_{1}^{+}) {=} m(\tilde{\chi}_{2}^{0}), \ m(\tilde{\chi}_{1}^{0}) {=} 0, \ sleptons \ decoupled \end{split}$	ATLAS-CONF-2013-049 ATLAS-CONF-2013-049 ATLAS-CONF-2013-028 ATLAS-CONF-2013-035 ATLAS-CONF-2013-035
Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^+$ Stable, stopped $\tilde{g}$ R-hadron GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(GMSB, \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}, \text{ long-lived } \tilde{\chi}_1^0 \rightarrow q \mu$ (RPV)	Disapp. trk 0 e, μ) 1-2 μ 2 γ 1 μ	1 jet 1-5 jets 0 0 0	Yes Yes - Yes Yes	20.3 22.9 15.9 4.7 4.4	$\tilde{x}_{1}^{\pm}$ 270 GeV $\tilde{g}$ 857 GeV $\tilde{x}_{1}^{0}$ 475 GeV $\tilde{x}_{1}^{0}$ 230 GeV $\tilde{q}$ 700 GeV	$\begin{split} &m(\tilde{\chi}_1^{\pm})\text{-}m(\tilde{\chi}_1^0)\text{=}160 \; MeV, \; \tau(\tilde{\chi}_1^{\pm})\text{=}0.2 \; ns \\ &m(\tilde{\chi}_1^0)\text{=}100 \; GeV, \; 10 \; \mu s < \tau(\tilde{g}) < 1000 \; s \\ &10 < \tan \! \beta < \! 50 \\ &0.4 < \tau(\tilde{\chi}_1^0) < \! 2 \; ns \\ &1 \; mm < \! c\tau < \! 1 \; m, \; \tilde{g} \; decoupled \end{split}$	ATLAS-CONF-2013-069 ATLAS-CONF-2013-057 ATLAS-CONF-2013-058 1304.6310 1210.7451
$ \begin{array}{c} \begin{array}{c} LFV pp \rightarrow \widetilde{v}_{\tau} + X, \widetilde{v}_{\tau} \rightarrow e + \mu \\ LFV pp \rightarrow \widetilde{v}_{\tau} + X, \widetilde{v}_{\tau} \rightarrow e(\mu) + \tau \\ Bilinear \ RPV \ CMSSM \\ \widetilde{x}_{1}^{+} \widetilde{x}_{1}^{-}, \widetilde{x}_{1}^{+} \rightarrow W \widetilde{x}_{1}^{0}, \widetilde{x}_{1}^{0} \rightarrow ee\widetilde{v}_{\mu}, e\mu \widetilde{v} \\ \widetilde{x}_{1}^{+} \widetilde{x}_{1}^{-}, \widetilde{x}_{1}^{+} \rightarrow W \widetilde{x}_{1}^{0}, \widetilde{x}_{1}^{0} \rightarrow \tau \tau \widetilde{v}_{e}, e\tau \widetilde{v} \\ \widetilde{g} \rightarrow qqq \\ \widetilde{g} \rightarrow \widetilde{t}_{1} t, \widetilde{t}_{1} \rightarrow bs \end{array} $	$\begin{array}{c} 2 \ e, \mu \\ 1 \ e, \mu + \tau \\ 1 \ e, \mu \\ \gamma_e \\ 4 \ e, \mu \\ \gamma_{\tau} \\ 3 \ e, \mu + \tau \\ 0 \\ 2 \ e, \mu \left( \text{SS} \right) \end{array}$	0 0 7 jets 0 0 6 jets 0-3 <i>b</i>	- Yes Yes Yes - Yes	4.6 4.6 4.7 20.7 20.7 4.6 20.7	$\tilde{v}_{\tau}$ 1 $\tilde{v}_{\tau}$ 1.1 TeV $\tilde{q}, \tilde{g}$ 1.2 TeV $\tilde{\chi}_{1}^{\pm}$ 760 GeV $\tilde{\chi}_{1}^{\pm}$ 350 GeV $\tilde{g}$ 666 GeV $\tilde{g}$ 880 GeV	<b>1.61 TeV</b> $\lambda'_{311}=0.10, \lambda_{132}=0.05$ $\lambda'_{311}=0.10, \lambda_{1(2)33}=0.05$ <b>V</b> $m(\tilde{q})=m(\tilde{g}), c\tau_{LSP}<1 \text{ mm}$ $m(\tilde{\chi}_{1}^{0})>300 \text{ GeV}, \lambda_{121}>0$ $m(\tilde{\chi}_{1}^{0})>80 \text{ GeV}, \lambda_{133}>0$	1212.1272 1212.1272 ATLAS-CONF-2012-140 ATLAS-CONF-2013-036 ATLAS-CONF-2013-036 1210.4813 ATLAS-CONF-2013-007
Scalar gluon WIMP interaction (D5, Dirac $\chi$ )	0 0	4 jets mono-jet	- Yes	4.6 10.5	sgluon 100-287 GeV M* scale 704 GeV	incl. limit from 1110.2693 m( $\chi$ )<80 GeV, limit of<687 GeV for D8	1210.4826 ATLAS-CONF-2012-147
√s = 7 TeV full data	$\sqrt{s} = 8 \text{ TeV}$	$\sqrt{s} = 8$ full of	8 TeV data		10 <sup>-1</sup> 1	Mass scale [TeV]	ted fo
*Only a selection of the availabl	le mass limit	ts on new	v states	s or phei	nomena is shown. All limits quoted are observed minus 1 $\sigma$ theor	retical signal cross section uncertainty.	oda

• Strategy ATLAS SUSY group: cover a wide range of final states and processes

### SUPERSYMMETRY IN ATLAS

#### ATLAS SUSY Searches\* - 95% CL Lower Limits

Status: EPS 2013

#### ATLAS Preliminary

 $\int \mathcal{L} dt = (4.4 - 22.9) \text{ fb}^{-1} \qquad \sqrt{s} = 7, 8 \text{ TeV}$ 

	Model	e, μ, τ, γ	Jets	$\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$	∫£ dt[fb	Mass limit	5	Reference
Inclusive Searches	$ \begin{array}{l} MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ \tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q \tilde{q} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q \tilde{q} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q q \tilde{\chi}_{1}^{0} \rightarrow q q W^{\pm} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g} \rightarrow q q q \ell (\ell \ell ) \tilde{\chi}_{1}^{0} \tilde{\chi}_{1} \\ GMSB (\tilde{\ell} \ NLSP) \\ GMSB (\tilde{\ell} \ NLSP) \\ GGM (bino \ NLSP) \\ GGM (mino \ NLSP) \\ GGM (higgsino-bino \ NLSP) \\ GGM (higgsino-bino \ NLSP) \\ GGM (higgsino \ NLSP) \\ GGM (higgsino \ NLSP) \\ GGM (higgsino \ NLSP) \\ Gravitino \ LSP \end{array} $	$\begin{array}{c} 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 1 \ e, \mu \end{array} \\ 2 \ e, \mu \ (SS) \\ 2 \ e, \mu \\ 1-2 \ \tau \\ 2 \ \gamma \\ 1 \ e, \mu + \gamma \\ \gamma \\ 2 \ e, \mu \ (Z) \\ 0 \end{array}$	2-6 jets 3-6 jets 7-10 jets 2-6 jets 3-6 jets 3-6 jets 3-6 jets 3-6 jets 0-2 jets 0 1 b 0-3 jets mono-jet	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.7 4.7 20.7 4.8 4.8 4.8 5.8 10.5	q. g       1.7 TeV         g       1.2 TeV         g       1.1 TeV         q       740 GeV         g       1.3 TeV         g       1.3 TeV         g       1.1 TeV         g       1.24 TeV         g       1.07 TeV         g       900 GeV         g       619 GeV         g       690 GeV         F <sup>1/2</sup> scale       645 GeV	$\begin{split} & m(\tilde{q}) \!=\! m(\tilde{g}) \\ & any \; m(\tilde{q}) \\ & any \; m(\tilde{q}) \\ & any \; m(\tilde{q}) \\ & m(\tilde{\chi}_1^0) \!=\! 0  GeV \\ & m(\tilde{\chi}_1^0) \!=\! 0  GeV \\ & m(\tilde{\chi}_1^0) \!<\! c50  GeV \\ & tan\beta \!<\! 15 \\ & tan\beta \! >\! 18 \\ & m(\tilde{\chi}_1^0) \!\!>\! 50  GeV \\ & m(\tilde{\chi}_1^0) \!\!>\! 50  GeV \\ & m(\tilde{\chi}_1^0) \!\!>\! 220  GeV \\ & m(\tilde{\chi}_1^0) \!\!>\! 220  GeV \\ & m(\tilde{\mathcal{H}}) \!\!>\! 200  GeV \\ & m(\tilde{g}) \!\!>\! 10^{-4}  eV \end{split}$	ATLAS-CONF-2013-047 ATLAS-CONF-2013-062 ATLAS-CONF-2013-054 ATLAS-CONF-2013-054 ATLAS-CONF-2013-067 ATLAS-CONF-2013-062 ATLAS-CONF-2013-062 1209.0753 ATLAS-CONF-2012-026 1209.0753 ATLAS-CONF-2012-144 1211.1167 ATLAS-CONF-2012-152 ATLAS-CONF-2012-147
3 <sup>rd</sup> gen. <i>ἒ</i> med.	$\begin{array}{l} \tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow b \bar{t} \tilde{\chi}_{1}^{+} \end{array}$	0 0 0-1 e,μ 0-1 e,μ	3 b 7-10 jets 3 b 3 b	Yes Yes Yes Yes	20.1 20.3 20.1 20.1	ğ1.2 TeVğDavid Côté1.14 TeVğ1.34 TeV1.3 TeV	$\begin{array}{l} m(\tilde{x}_{1}^{0}) \!<\! 600  \mathrm{GeV} \\ m(\tilde{x}_{1}^{0}) \!<\! 200  \mathrm{GeV} \\ m(\tilde{x}_{1}^{0}) \!<\! 400  \mathrm{GeV} \\ m(\tilde{x}_{1}^{0}) \!<\! 300  \mathrm{GeV} \end{array}$	ATLAS-CONF-2013-061 ATLAS-CONF-2013-054 ATLAS-CONF-2013-061 ATLAS-CONF-2013-061
3 <sup>rd</sup> gen. squarks direct production	$ \begin{array}{l} \tilde{b}_{1} \tilde{b}_{1}, \tilde{b}_{1} \rightarrow b \tilde{\chi}_{1}^{0} \\ \tilde{b}_{1} \tilde{b}_{1}, \tilde{b}_{1} \rightarrow t \tilde{\chi}_{1}^{\pm} \\ \tilde{t}_{1} \tilde{t}_{1} (\text{light}), \tilde{t}_{1} \rightarrow b \tilde{\chi}_{1}^{\pm} \\ \tilde{t}_{1} \tilde{t}_{1} (\text{light}), \tilde{t}_{1} \rightarrow W b \tilde{\chi}_{1}^{0} \\ \tilde{t}_{1} \tilde{t}_{1} (\text{medium}), \tilde{t}_{1} \rightarrow t \tilde{\chi}_{1}^{0} \\ \tilde{t}_{1} \tilde{t}_{1} (\text{medium}), \tilde{t}_{1} \rightarrow t \tilde{\chi}_{1}^{0} \\ \tilde{t}_{1} \tilde{t}_{1} (\text{heavy}), \tilde{t}_{1} \rightarrow t \tilde{\chi}_{1}^{0} \\ \tilde{t}_{1} \tilde{t}_{1} (\text{heavy}), \tilde{t}_{1} \rightarrow t \tilde{\chi}_{1}^{0} \\ \tilde{t}_{1} \tilde{t}_{1} (\text{neatural GMSB}) \\ \tilde{t}_{2} \tilde{t}_{2}, \tilde{t}_{2} \rightarrow \tilde{t}_{1} + Z \end{array} $	$\begin{array}{c} 0\\ 2\ e,\mu\ ({\rm SS})\\ 1{-}2\ e,\mu\\ 2\ e,\mu\\ 0\\ 1\ e,\mu\\ 0\\ 1\ e,\mu\\ 0\\ 3\ e,\mu\ (Z) \end{array}$	2 b 0-3 b 1-2 b 0-2 jets 2 jets 2 b 1 b 2 b 1 ono-jet/c-t 1 b 1 b	Yes Yes Yes Yes Yes Yes Yes ag Yes Yes Yes	20.1 20.7 4.7 20.3 20.3 20.1 20.7 20.5 20.3 20.7 20.7	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{l} m(\tilde{\chi}_{1}^{0}) < 100  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{+}) = 2  m(\tilde{\chi}_{1}^{0}) \\ m(\tilde{\chi}_{1}^{0}) = 55  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 56  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 0  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) < 200  \mathrm{GeV},  m(\tilde{\chi}_{1}^{+}) \cdot m(\tilde{\chi}_{1}^{0}) = 5  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 0  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 0  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 0  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 150  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) > 150  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 160  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 150  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 150  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 150  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 160  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 150  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 150  \mathrm{GeV} \\ m(\tilde{\chi}_{1}^{0}) = 100  \mathrm{GeV} \\ m$	ATLAS-CONF-2013-053 ATLAS-CONF-2013-007 1208.4305, 1209.2102 ATLAS-CONF-2013-048 ATLAS-CONF-2013-055 ATLAS-CONF-2013-053 ATLAS-CONF-2013-024 ATLAS-CONF-2013-024 ATLAS-CONF-2013-025 ATLAS-CONF-2013-025
EW direct	$ \begin{array}{c} \tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_{1}^{0} \\ \tilde{\chi}_{1}^{+}\tilde{\chi}_{1}^{-}, \tilde{\chi}_{1}^{+} \rightarrow \tilde{\ell}\nu(\ell\tilde{\nu}) \\ \tilde{\chi}_{1}^{+}\tilde{\chi}_{1}^{-}, \tilde{\chi}_{1}^{+} \rightarrow \tilde{\tau}\nu(\tau\tilde{\nu}) \\ \tilde{\chi}_{1}^{\pm}\tilde{\chi}_{2}^{0} \rightarrow \tilde{\ell}_{L}\nu\tilde{\ell}_{L}\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_{L}\ell(\tilde{\nu}\nu) \\ \tilde{\chi}_{1}^{\pm}\tilde{\chi}_{2}^{0} \rightarrow W^{*}\tilde{\chi}_{1}^{0}Z^{*}\tilde{\chi}_{1}^{0} \end{array} $	2 e, μ 2 e, μ 2 τ 3 e, μ 3 e, μ	0 0 0 0	Yes Yes Yes Yes Yes	20.3 20.3 20.7 20.7 20.7	$ \begin{array}{c c} \tilde{\ell} & & & \\ \tilde{\chi}_{1}^{\pm} & & & \\ \tilde{\chi}_{1}^{\pm} , \tilde{\chi}_{2}^{0} & & & \\ \tilde{\chi}_{1}^{\pm} , \tilde{\chi}_{2}^{0} & & & \\ \tilde{\chi}_{1}^{\pm} , \tilde{\chi}_{2}^{0} & & & \\ \end{array} \\ \hline \begin{array}{c} \tilde{\ell} & & & \\ Samuel ~ Kin8 \\ \hline \\ Samuel ~ & & \\ \hline \\ Samuel ~ & \\ \hline \\$	$\begin{array}{l} m(\tilde{\chi}_{1}^{0}){=}0\text{GeV} \\ m(\tilde{\chi}_{1}^{0}){=}0\text{GeV},m(\tilde{\ell},\tilde{\nu}){=}0.5(m(\tilde{\chi}_{1}^{\pm}){+}m(\tilde{\chi}_{1}^{0})) \\ m(\tilde{\chi}_{1}^{0}){=}0\text{GeV},m(\tilde{\tau},\tilde{\nu}){=}0.5(m(\tilde{\chi}_{1}^{\pm}){+}m(\tilde{\chi}_{1}^{0})) \\ sm(\tilde{\chi}_{2}^{0}),m(\tilde{\chi}_{1}^{0}){=}0,m(\tilde{\ell},\tilde{\nu}){=}0.5(m(\tilde{\chi}_{1}^{\pm}){+}m(\tilde{\chi}_{1}^{0})) \\ m(\tilde{\chi}_{1}^{\pm}){=}m(\tilde{\chi}_{2}^{0}),m(\tilde{\chi}_{1}^{0}){=}0,\text{sleptons decoupled} \end{array}$	ATLAS-CONF-2013-049 ATLAS-CONF-2013-049 ATLAS-CONF-2013-028 ATLAS-CONF-2013-035 ATLAS-CONF-2013-035
Long-lived particles	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^+$ Stable, stopped $\tilde{g}$ R-hadron GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(\tilde{e}, \tilde{g}) + \tau(\tilde$	Disapp. trk 0 e, μ) 1-2 μ 2 γ 1 μ	1 jet 1-5 jets 0 0 0	Yes Yes - Yes Yes	20.3 22.9 15.9 4.7 4.4	$\begin{array}{c} \tilde{x}_{1}^{\pm} & 270 \\ \tilde{g} & \\ \tilde{x}_{1}^{0} & \\ \tilde{q} & \\ \end{array} \\ \begin{array}{c} \tilde{x}_{1}^{0} \\ \tilde{q} & \\ \end{array} \\ \begin{array}{c} \tilde{x}_{1}^{0} \\ Massimo \\ \end{array} \\ \begin{array}{c} \tilde{x}_{1}^{0} \\ \tilde{y} & \\ \end{array} \\ \begin{array}{c} \tilde{y}_{1} \\ \tilde{y}$	$\begin{array}{l} m(\tilde{\chi}_1^{\pm}) \! \! \! \! \! - \! m(\tilde{\chi}_1^0) \! \! \! \! = \! 160 \; MeV, \; \! \tau(\tilde{\chi}_1^{\pm}) \! \! \! = \! 0.2 \; ns \\ m(\tilde{\chi}_1^0) \! \! \! \! = \! 100 \; GeV, \; \! 10 \; \! \mu \! s \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \!$	ATLAS-CONF-2013-069 ATLAS-CONF-2013-057 ATLAS-CONF-2013-058 1304.6310 1210.7451
RPV	$ \begin{array}{c} LFV \ pp \rightarrow \tilde{v}_{\tau} + X, \ \tilde{v}_{\tau} \rightarrow e + \mu \\ LFV \ pp \rightarrow \tilde{v}_{\tau} + X, \ \tilde{v}_{\tau} \rightarrow e(\mu) + \tau \\ Bilinear \ RPV \ CMSSM \\ \tilde{\chi}_{1}^{+} \tilde{\chi}_{1}^{-}, \ \tilde{\chi}_{1}^{+} \rightarrow W \tilde{\chi}_{1}^{0}, \ \tilde{\chi}_{1}^{0} \rightarrow ee\tilde{v}_{\mu}, e\mu \tilde{v} \\ \tilde{\chi}_{1}^{+} \tilde{\chi}_{1}^{-}, \ \tilde{\chi}_{1}^{+} \rightarrow W \tilde{\chi}_{1}^{0}, \ \tilde{\chi}_{1}^{0} \rightarrow \tau \tau \tilde{v}_{e}, e\tau \tilde{v} \\ \tilde{g} \rightarrow qqq \\ \tilde{g} \rightarrow \tilde{t}_{1} t, \ \tilde{t}_{1} \rightarrow bs \end{array} $	$\begin{array}{c} 2 \ e, \mu \\ 1 \ e, \mu + \tau \\ 1 \ e, \mu \\ \vec{v}_{e} \\ \vec{v}_{e} \\ \vec{v}_{e} \\ 3 \ e, \mu + \tau \\ 0 \\ 2 \ e, \mu \left( \text{SS} \right) \end{array}$	0 0 7 jets 0 0 6 jets 0-3 <i>b</i>	- Yes Yes - Yes	4.6 4.6 4.7 20.7 20.7 4.6 20.7	$ \begin{array}{c} \tilde{v}_{r} & 1.12 \\ \tilde{v}_{r} & 1.61 \text{ TeV} \\ \tilde{q}, \tilde{g} & \\ \tilde{x}_{1}^{\pm} & \\ \tilde{x}_{1}^{\pm} & \\ \tilde{g} & \\ \hline \\ \tilde{g} & \\ \end{array} \\ \begin{array}{c} 1.61 \text{ TeV} \\ 1.1 \text{ TeV} \\ 1.2 \text{ TeV} \\ \hline \\ \tilde{g} & \\ \hline \\ \tilde{g} & \\ \end{array} \\ \begin{array}{c} 800 \text{ GeV} \\ \hline \\ 880 \text{ GeV} \\ \end{array} $	$ \begin{split} \lambda'_{311} = & 0.10, \ \lambda_{132} = 0.05 \\ \lambda'_{311} = & 0.10, \ \lambda_{1(2)33} = 0.05 \\ m(\tilde{q}) = & m(\tilde{g}), \ c\tau_{LSP} < 1 \ mm \\ m(\tilde{\chi}_1^0) > & 300 \ GeV, \ \lambda_{121} > 0 \\ m(\tilde{\chi}_1^0) > & 80 \ GeV, \ \lambda_{133} > 0 \end{split} $	1212.1272 1212.1272 ATLAS-CONF-2012-140 ATLAS-CONF-2013-036 ATLAS-CONF-2013-036 1210.4813 ATLAS-CONF-2013-007
Other	Scalar gluon WIMP interaction (D5, Dirac $\chi$ )	0 0	4 jets mono-jet	Yes	4.6 10.5	sgluon 100-287 GeV M* scale 704 GeV	incl. limit from 1110.2693 m( $\chi$ )<80 GeV, limit of<687 GeV for D8	1210.4826 ATLAS-CONF-2012-147
	√s = 7 TeV full data p	$\sqrt{s} = 8 \text{ TeV}$	√s = full	8 TeV data		10 <sup>-1</sup> 1	Mass scale [TeV]	J

\*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1 $\sigma$  theoretical signal cross section uncertainty.

• A large number of posters presenting more details

### **OVERVIEW**

- Motivation inclusive searches:
  - SUSY predicts existence of new colored particles
  - If present at TeV-scale, "high discovery potential" at LHC
    - Benchmark for LHC/ATLAS performance
  - R-parity conserving (RPC) models:
    - LSP stable (dark matter candidate)
    - Many energetic decay products:
      - multiple jets
      - large missing ET (MET)
      - possibly lepton(s)
        - <u>hard</u>:  $pT(lep) \ge 25 \text{ GeV}$
        - <u>soft</u>: pT(lep) < 25 GeV



- Focus (on newest results) on inclusive RPC SUSY strong production searches:
  - I-2 leptons + 3-6 jets + MET: <u>ATLAS-CONF-2013-062</u>
  - 0 leptons + 2-6 jets + MET: <u>ATLAS-CONF-2013-047</u>
  - 0 leptons + 7-10 jets + MET: <u>ATLAS-CONF-2013-054</u>
  - All ATLAS SUSY public results <u>AtlasPublic/SupersymmetryPublicResults</u>
- Outline of this talk:
  - Analyses + Backgrounds + Signal Regions
  - Results
  - Interpretation

### ANALYSES + BACKGROUNDS + SIGNAL REGIONS

### BACKGROUND - OL + 2-6] + MET ATLAS-CONF-2013-047

- **MET + jets:** "high discovery potential" of strong production SUSY at hadron collider •
- Very powerful, even in busy LHC environment
- Main discriminating variables: MET + effective mass meff
- **O-lepton** analysis focus: short/medium/long decay chains

$$m_{\text{eff}} \equiv \sum_{i=1}^{n} |\mathbf{p}_{\text{T}}^{(i)}| + E_{\text{T}}^{\text{miss}}$$

- Five inclusive channels based on jet multiplicity 2 / 3 / 4 / 5 / 6 jets + lepton veto ٠
  - optimized for squark or gluino pair (or mixed) production •
- Up to three **signal regions (SR)** per channel, based on tighter meff (details in backup)



4 jets channel



- Irreducible dominant backgrounds estimated ٠ with Combined Fit Method:
  - (I) Bkg-only fit: Normalize Monte Carlo (MC) to data in simultaneous fit of control regions (CR)
  - (2) Include systematic experimental/theoretical uncertainties as nuisance parameters
  - (3) Exclusion fit: Signal model can be included in signal/control regions for exclusion
    - Used in all discussed analyses

Poster: Valerio Consorti

Inclusive SUSY searches - EPSHEP 2013

### BACKGROUND - 0L + 7-I0J + MET

- What if SUSY mass/decay spectrum more complex?
- <u>O-lepton + multijets</u> analysis targets very long decay chains
- Multijet production QCD, ttbar/W+jets/Z+jets fully hadronic estimated with a dedicated **data-driven** method, based on the observation that:
  - MET resolution proportional to  $\sqrt{HT}$  in jet dominated events  $\Rightarrow MET/\sqrt{HT} \sim independent$  of jet multiplicity
    - HT = scalar sum of pT of all jets with pT > 40 GeV
    - stochastic variations in measured jet energies
  - Use lower jet multiplicity to retrieve MET/√HT shape from data
  - Use lower MET/√HT to normalize background to data
- Signal regions defined by:
  - MET/ $\sqrt{HT} > 4 \sqrt{GeV}$
  - jet multiplicity  $7 / 8 / 9 / \ge 10$  jets
    - pT(jet) > 50 (80) GeV

MET/ $\sqrt{HT}$  shape 7 jets control region





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# BACKGROUND - HARD IL + 3-6J + MET

- Trigger / detectors / world not perfect → leptons help in LHC environment
- Leptonic final state cleaner, easier to trigger, but rare (W/Z/slepton in decay chain)
- Leptonic analyses target different decay modes, rejected by 0-lepton analyses
- Extra variables help distinguish backgrounds from signal:
  - Transverse Mass MT (using angular information):

$$m_{\rm T} = \sqrt{2 \cdot p_{\rm T}^{\ell} \cdot E_{\rm T}^{\rm miss}} \cdot (1 - \cos(\Delta \phi(\vec{\ell}, \vec{E}_{\rm T}^{\rm miss}))).$$

#### ATLAS-CONF-2013-062



- Hard I lepton (electron or muon) signal regions, pT(lep) > 25 GeV defined as:
  - 3 / 5 / 6 jets + high MT + high MET + high meff
- Control regions in leptonic searches typically:
  - At lower MET/MT
  - Subdivided into b-tagged (ttbar enriched) and b-vetoed (W+jets enriched) regions



Poster: Jeanette Lorenz

A. Koutsman

# BACKGROUND - SOFT IL + 2-5J + MET

- What if SUSY is not "simple" strong production? ٠
- In **compressed** SUSY spectra, leptons in decay chain expected to be soft
  - Fully compressed spectrum: small  $\Delta M$
  - Compressed chargino/neutralino sector: small  $\Delta m$ •
- Soft I lepton signal regions ٠ 6[µ](10[e]) < pT(lep) < 25 GeV:
  - 3 jets / 5 jets + high MET + high MT
- Complimentary to hard 1-lepton  $\rightarrow$  "hard-to-reach" diagonal
- Experimentally challenging  $\rightarrow$  need hard **ISR jet**: •
  - Trigger signal (MET trigger)
  - Boost fully compressed spectra



 $\widetilde{g} \text{-} \widetilde{g} \rightarrow qqqqWW \widetilde{\chi}_{_{1}}^{^{0}} \widetilde{\chi}_{_{1}}^{^{0}}, x \text{=} 1/2$ 

ATLAS-CONF-2013-062

#### [GeV] 100 Numbers give 95% CL excluded model cross sections [pb] 900 m(LSP) 800 2 ml 700 Meluino 600 soft lepton, small $\Delta M$ Leading jet 500 qq400 p300 Soft-lepton hard lepton 200 large $\Delta M$ 100 400 600 800 1000 1200 1400 [GeV] qm(gluino) **mET** Poster: Ljiljana Morvaj 9 0.1

### RESULTS

### **RESULTS - 0 LEPTON**

- No significant excess in any signal region (details in back up)
- Data and estimated backgrounds used to set model-independent limits on visible BSM cross section
  - No signal model used, in contrast to model interpretations (next)
  - σ(vis) < 0.12 fb
    - $\sigma(vis) = \sigma(BSM) \times Acceptance \times efficiency$



### **RESULTS - I LEPTON**

- No significant excess in any signal region (details in back up)
- Data and estimated backgrounds used to set **model-independent limits** on visible BSM cross section
  - σ(vis) < 0.15 fb



### INTERPRETATIONS

### MSUGRA/CMMSM

- "Higgs-aware" MSUGRA/CMSSM plane
- Gluino masses below ~1.35TeV excluded for all squark masses





### SIMP. MODELS: GLUINO VIA CHARGINO



Inclusive SUSY searches - EPSHEP 2013

### SIMP. MODELS: SQUARK VIA CHARGINO



### SIMP. MODELS: VIA CHARGINO/NETRALINO2



### SUMMARY

- LHC and ATLAS very powerful pairing in search for SUSY
- Unfortunately no sign of supersymmetric phenomena yet
- Excluding gluinos (squarks) with masses up to ~1.3 (0.75) TeV in studied models
- Model-independent limits on visible cross section for BSM physics as low as 0.12 fb

### ATLAS SUSY Searches\* - 95% CL Lower Limits

Status: EPS 2013

	Model	e, μ, τ, γ	Jets	$E_{T}^{miss}$	∫£ dt[fb	<b>D</b> <sup>-1</sup> ]	Mass limit		Reference
	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	q, g	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, µ	3-6 jets	Yes	20.3	ğ	1.2 TeV	any m $(\tilde{q})$	ATLAS-CONF-2013-062
6	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	ğ	1.1 TeV	any m $(\tilde{q})$	ATLAS-CONF-2013-054
ĕ	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	q	740 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$	ATLAS-CONF-2013-047
ζ,	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	ğ	1.3 TeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$	ATLAS-CONF-2013-047
98	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq\tilde{\chi}_{1}^{\pm} \rightarrow qqW^{\pm}\tilde{\chi}_{1}^{0}$	1 e, µ	3-6 jets	Yes	20.3	ĝ	1.18 TeV	$m(\tilde{\chi}_{1}^{0}) < 200 \text{ GeV}, m(\tilde{\chi}^{\pm}) = 0.5(m(\tilde{\chi}_{1}^{0}) + m(\tilde{g}))$	ATLAS-CONF-2013-062
Š	$\tilde{g}\tilde{g} \rightarrow qqqq\ell\ell(\ell\ell)\tilde{\chi}_1^0\tilde{\chi}_1^0$	2 e,μ (SS)	3 jets	Yes	20.7	ğ	1.1 TeV	$m(\tilde{\chi}_1^0) < 650  \text{GeV}$	ATLAS-CONF-2013-007
Ve Ve	GMSB $(\tilde{\ell} NLSP)$	2 e, µ	2-4 jets	Yes	4.7	ğ	1.24 TeV	$\tan\beta < 15$	1208.4688
ISI	GMSB ( $\tilde{\ell}$ NLSP)	1-2 $ au$	0-2 jets	Yes	20.7	ğ	1.4 TeV	$\tan\beta > 18$	ATLAS-CONF-2013-026
5	GGM (bino NLSP)	2γ	0	Yes	4.8	Ğ	1.07 TeV	$m(\tilde{\chi}_1^0) > 50  \text{GeV}$	1209.0753
<u>Ē</u>	GGM (wino NLSP)	$1 e, \mu + \gamma$	0	Yes	4.8	ĝ	619 GeV	$m(\tilde{\chi}_1^0)$ >50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 <i>b</i>	Yes	4.8	Ğ	900 GeV	$m(\tilde{\chi}_1^0)>220  GeV$	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Ζ)	0-3 jets	Yes	5.8	ĝ	690 GeV	$m(\tilde{H})>200 \mathrm{GeV}$	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	F <sup>1/2</sup> scale	645 GeV	$m(\widetilde{g}) > 10^{-4} eV$	ATLAS-CONF-2012-147

#### • <u>Next steps</u>:

- Finalize all ongoing 8 TeV analyses on full 2012 dataset
- Move forward to produce combined 0L + IL + 2L + ... exclusions by full statistical analyses combination
- 13~14 TeV: the big next step in mass reach for inclusive searches for squarks and gluinos (fingers crossed)

**ATLAS** Preliminary

 $\int \mathcal{L} dt = (4.4 - 22.9) \text{ fb}^{-1}$   $\sqrt{s} = 7, 8 \text{ TeV}$ 

### FOUND IT



Los Roques, Venezuela June 2013

### **BACK UP**

### SIMPLIFIED MODELS: DIRECT PRODUCTION



Inclusive SUSY searches - EPSHEP 2013





### MINIMAL UED

- Limits in minimal Universal Extra Dimensions (mUED)
- Signal region: 2 soft muons + 2 jets + high MET + high MT + Z-veto
- Comparable expected limits, but observed limit worse for 2L because of slight excess



0L+2-6J+MET



### SIMP. MODELS: GLUINO VIA SLEPTON



### SIMP. MODELS: SQUARK VIA SLEPTON



### COMBINED FIT METHOD

- Combined Fit Method:
  - (1) Take shape of variable (MET,MT) distributions from Monte Carlo
  - (2) Combine all backgrounds in a likelihood model with free normalization parameters for dominant backgrounds
  - (3) Select signal-free control regions and fit model to data
  - (4) Extrapolate to signal regions using MC shape and fitted normalizations
  - (5) Systematic experimental/theoretical uncertainties included as Gaussian constraints
  - (6) Systematics can be constrained if enough information in fit  $\rightarrow$  "profiling"
  - (7) MC statistical uncertainties can be included as Poisson errors
  - (8) Signal can be included in signal regions for exclusion
  - (9) Shape information (binned fit) easily added for better discriminating power
  - (10) Statistically independent validation regions used to cross check SM predictions/extrapolation with data
  - Combining all useful information into a global Likelihood:

$$L(\mathbf{n}|s, \mathbf{b}, \boldsymbol{\theta}) = P_{\mathrm{S}} \times P_{\mathrm{W}} \times P_{\mathrm{T}} \times C_{\mathrm{Syst}},$$

- **n** = number of observed events
- **s** = SUSY signal to be tested
- b = background normalization parameters, shared between all fit regions
- $\theta$  = systematic uncertainties, treated as nuisance parameters with a Gaussian constraint
- **Ps (w,T)** = (Poisson) probability density functions (pdfs) for event counts in signal/control regions
- **Csyst** = constraints on systematic uncertainties, proper treatment of correlations
- Simultaneous fit of multiple control (+signal) regions normalizes the backgrounds (and signal)

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## SIGNAL REGIONS IL + 2-6J + MET

- Hard I lepton signal regions, pT(lep) > 25 GeV:
  - 3 jets / 5 jets / 6 jets + high MET + high MT
    + high Meff

#### ATLAS-CONF-2013-062

	in	clusive (binned) hard	single-lepton
	3-jet	5-jet	6-jet
$N_\ell$		1 (electron or m	uon)
$p_{\rm T}^{\ell}({\rm GeV})$		> 25	
$p_{\mathrm{T}}^{\mathrm{add.}\ \ell}$ (GeV)		< 10	
N <sub>jet</sub>	≥ 3	≥ 5	$\geq 6$
$p_{\rm T}^{\rm jet}({\rm GeV})$	> 80, 80, 30	> 80, 50, 40, 40, 40	> 80, 50, 40, 40, 40, 40
$p_{\mathrm{T}}^{\mathrm{add. jets}}(\mathrm{GeV})$	- (< 40)	- (< 40)	_
$E_{\rm T}^{\rm miss}$ (GeV)	>500 (300)	>300	>350 (250)
$m_{\rm T}~({\rm GeV})$	> 150	> 200 (150)	> 150
$E_{\rm T}^{\rm miss}/m_{\rm eff}^{\rm excl}$	> 0.3	_	_
$m_{\rm eff}^{\rm incl}  ({\rm GeV})$	> ]	1400 (800)	> 600

- Soft I lepton signal regions, 6[µ](I0[e]) < pT(lep) < 25 GeV:</li>
  - 3 jets / 5 jets + high MET + high MT
- Soft 2 muons signal region (target mUED):
  - high MET + high MT + Z-veto

		soft single-lepton	soft dimuon			
	3-jet	5-jet	2-jet			
$N_\ell$	-	l (electron or muon)	2 (muons)			
$p_{\mathrm{T}}^{\ell}(\mathrm{GeV})$	[10,25]	(electron), [6,25] (muon)	[6,25]			
$p_{\mathrm{T}}^{\mathrm{add.} \ell}$ (GeV)		< 7 (electron), <	6 (muon)			
$m_{\mu\mu}$ (GeV)	—	_	>15 and $ m_{\mu\mu} - m_Z  > 10$			
N <sub>jet</sub>	[3,4]	≥ 5	≥ 2			
$p_{\rm T}^{\rm leading jet}({\rm GeV})$		> 180	>70			
$p_{\rm T}^{\rm subleading jets}({\rm GeV})$		> 25				
N <sub>b-tag</sub>	—	_	0			
$E_{\rm T}^{\rm miss}$ (GeV)	>400	>300	>170			
$m_{\rm T}~({\rm GeV})$		> 100	> 80			
$E_{\rm T}^{\rm miss}/m_{\rm eff}^{\rm incl}$		> 0.3	_			
$\Delta R_{\min}(\text{jet}, \ell)$	> 1.0	_	> 1.0			

Example: 3 jets, after fit

## SIGNAL REGIONS OL + 2-10J + MET

#### ATLAS-CONF-2013-047

- Five inclusive channels based on jet multiplicity - 2-6 jets - optimized for squark/gluino pair (mixed) production
  - Up to three signal regions for each channel based on tighter meff cuts
    - $\rightarrow$  TOTAL: 10 signal regions (SR)

		Channel								
Requirement	uirementA (2-jets)B (3-jets)C (4-jets)LMMTMT		D (5-jets) E (6-jets)			)				
			-	L	М	Т				
$E_{\rm T}^{\rm miss}[{\rm GeV}] >$					160	)				
$p_{\mathrm{T}}(j_1) [\mathrm{GeV}] >$					130	)				
$p_{\mathrm{T}}(j_2) [\mathrm{GeV}] >$		60								
$p_{\rm T}(j_3) [{\rm GeV}] >$	-	- 60			60 60				60	
$p_{\mathrm{T}}(j_4) [\mathrm{GeV}] >$	-	-		_	6	0	60	60		
$p_{\mathrm{T}}(j_5) [\mathrm{GeV}] >$	-	-		_	- 60			60		
$p_{\mathrm{T}}(j_{6})  \mathrm{[GeV]} >$	-	-		_				60		
$\Delta \phi(\text{jet}_i, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$	0.4 ( <i>i</i> =	= {1, 2, (3	$3  ext{ if } p_{\mathrm{T}}(j_3)$	) > 40 GeV)})	0.4 ( $i = \{1, 2, 3\}$ ), 0.2 ( $p_T > 40$ GeV jets)					)
$E_{\rm T}^{\rm miss}/m_{\rm eff}(Nj) >$	0.2	_a	0.3	0.4	0.25	0.25	0.2	0.15	0.2	0.25
$m_{\rm eff}({\rm incl.}) [{\rm GeV}] >$	1000	1600	1800	2200	1200	2200	1600	1000	1200	1500

#### ATLAS-CONF-2013-054

		Multi-jet + flavo					et + flavour	r stream						$\text{Multi-jet} + M_J^{\Sigma} \text{ stream}$		
Identifier		8j!	50		9j	50	$\geq 10 \mathrm{j} 50$		7	j80		$\geq 8$	j80	$\geq 8 \mathbf{j} 50$	$\geq 9 \mathbf{j} 50$	$\geq 10 \mathrm{j} 50$
Jet $ \eta $		< 2.0				< 2.0			< 2.8							
Jet $p_{\rm T}$		$> 50 \mathrm{GeV}$				$> 80 \mathrm{GeV}$			$> 50 \mathrm{GeV}$							
Jet count		=	8		=	9	$\geq 10$		=	- 7		$\geq$	8	$\geq 8$	$\geq 9$	$\geq 10$
b-jets ( $p_{\rm T} > 40 \ { m GeV},  \eta  < 2.5$ )	0	1	$\geq 2$	0	1	$\geq 2$		0	1	$\geq 2$	0	1	$\geq 2$			
$M_J^{\Sigma}$ [GeV]					_				> 340 and $> 420$ for each case							
$E_{\rm T}^{\rm miss}/\sqrt{H_{\rm T}}$				>	4 G	$eV^{1/2}$		$> 4 {\rm GeV}^{1/2}$			$> 4 \text{ GeV}^{1/2}$					

- Signal regions defined by:
  - jet multiplicity (7  $\geq$  10 jets)
    - b-tagged jet multiplicity
    - MJΣ = mass of large-radius jet
  - MET/ $\sqrt{HT} > 4 \sqrt{GeV}$ 
    - → TOTAL 19 signal regions

### LARGE-RADIUS JET MASS

Highly boosted particles expected to form large-radius ('composite') massive jets

#### ATLAS-CONF-2013-054



- Form large radius (R=1.0) anti-kt jets from nominal R=0.4 jets
- $MJ\Sigma$  = sum of the masses of composite jets:

$$M_J^{\Sigma} \equiv \sum_j m_j^{R=1.0}$$

- pT(R=1.0 jet) > 100 GeV
- |eta (R=1.0 jet)| < 1.5
- **Signal regions** defined for two MJΣ thresholds:
  - MJΣ > 340 GeV
  - MJΣ > 420 GeV
  - jet multiplicity  $8/9/ \ge 10$  jets pT(jet) > 50 GeV



### RESULTS

- No significant excess in any signal region
- Data and estimated backgrounds used to set model-independent limits on visible BSM cross section
  - $\sigma(vis) = \sigma(BSM) \times Acceptance \times efficiency$
  - p0 = p(s=0) = p-value of background-only hypothesis

|--|

			inclusive ha	rd single-lept	on	
	3	3-jet	5-	jet	6-	jet
	electron	muon	electron	muon	electron	muon
Observed events	4	5	4	2	2	0
Fitted background events	$3.9 \pm 1.0$	$2.7 \pm 0.9$	3.6 ± 1.0	$2.5 \pm 0.8$	$2.0 \pm 0.7$	1.7 ± 0.6
Fitted <i>tt</i> events	$1.4 \pm 0.5$	$1.6 \pm 0.5$	$2.7 \pm 0.8$	$2.0 \pm 0.7$	$1.3 \pm 0.5$	$1.3 \pm 0.5$
Fitted W+jets events	$0.9\pm0.4$	$0.6 \pm 0.5$	$0.11 \pm 0.08$	$0.08\pm0.08$	$0.00\pm0.00$	$0.07^{+0.15}_{-0.07}$
Fitted diboson events	$0.8\pm0.5$	$0.4 \pm 0.2$	$0.7 \pm 0.4$	$0.10\pm0.05$	$0.06\pm0.04$	$0.00 \pm 0.00$
Fitted misidentified lepton events	$0.15^{+0.17}_{-0.15}$	$0.00\pm0.02$	$0.00\pm0.01$	$0.00\pm0.01$	$0.00\pm0.00$	$0.00\pm0.00$
Fitted other background events	$0.6 \pm 0.3$	$0.09 \pm 0.05$	$0.12\pm0.07$	$0.3\pm0.1$	$0.7 \pm 0.3$	$0.3\pm0.1$
MC expected SM events	$4.2\pm1.1$	$2.9 \pm 1.0$	3.6 ± 0.9	$2.4 \pm 0.7$	$2.1 \pm 0.8$	1.9 ± 0.7
MC expected $t\bar{t}$ events	$1.3 \pm 0.4$	$1.5 \pm 0.4$	$2.6 \pm 0.7$	$1.9 \pm 0.6$	$1.4 \pm 0.5$	$1.4 \pm 0.5$
MC expected W+jets events	$1.3 \pm 0.5$	$0.9 \pm 0.7$	$0.2 \pm 0.1$	$0.1 \pm 0.1$	$0.0 \pm 0.0$	$0.1^{+0.2}_{-0.1}$
MC expected diboson events	$0.8\pm0.5$	$0.4 \pm 0.2$	$0.7 \pm 0.4$	$0.10\pm0.05$	$0.07\pm0.04$	$0.00 \pm 0.00$
data-driven misidentified lepton events	$0.15^{+0.17}_{-0.15}$	$0.00\pm0.02$	$0.00\pm0.01$	$0.00\pm0.01$	$0.00\pm0.00$	$0.00\pm0.00$
MC expected other background events	$0.6 \pm 0.3$	$0.09 \pm 0.05$	$0.13 \pm 0.07$	$0.3\pm0.1$	$0.6 \pm 0.3$	$0.3\pm0.1$

	soft sing	gle-lepton	soft dimuon
	3-jet	5-jet	2-jet
Observed events	7	9	7
Fitted background events	5.6 ± 1.6	$14.8 \pm 3.7$	1.6 ± 1.0
Fitted <i>tī</i> events	$1.3 \pm 1.0$	7.8 ± 3.3	$1.2 \pm 1.0$
Fitted W+jets events	$2.6 \pm 0.7$	$2.1 \pm 0.9$	-
Fitted diboson events	$0.6 \pm 0.4$	$0.7 \pm 0.4$	$0.4 \pm 0.3$
Fitted misidentified lepton events	$0.00^{+0.05}_{-0.00}$	$3.3 \pm 1.4$	0.0+0.3
Fitted other background events	$1.1 \pm 0.5$	$0.9 \pm 0.5$	$0.01_{-0.01}^{+0.06}$
MC expected SM events	6.3 ± 1.9	$15.9 \pm 3.8$	1.9 ± 1.2
MC expected <i>tī</i> events	$1.4 \pm 1.1$	7.8 ± 3.0	1.5 ± 1.2
MC expected W+jets events	$3.1 \pm 0.9$	$3.2 \pm 0.9$	-
MC expected diboson events	$0.6 \pm 0.4$	$0.7 \pm 0.4$	$0.4 \pm 0.3$
data-driven misidentified lepton events	$0.00^{+0.05}_{-0.00}$	$3.3 \pm 1.4$	$0.0^{+0.3}_{-0.0}$
MC expected other background events	$1.1 \pm 0.6$	$0.9 \pm 0.4$	$0.01^{+0.06}_{-0.01}$

Signal channel	$\langle \epsilon \sigma \rangle_{\rm obs}^{95} [{\rm fb}]$	$S_{\rm obs}^{95}$	$S_{exp}^{95}$	$CL_B$	p(s = 0)
soft single-lepton chan	nels				
3-jet	0.40 (0.39)	8.1 (8.1)	$7.3^{+2.7}_{-1.8}$ (6.8 <sup>+3.3</sup> <sub>-2.1</sub> )	0.67 (0.66)	0.36 (0.31)
5-jet	0.35 (0.33)	7.1 (6.8)	$10.0^{+3.6}_{-3.0} (9.8^{+4.2}_{-2.9})$	0.15 (0.15)	0.50 (0.50)
soft dimuon channel	0.57 (0.54)	11.5 (11.1)	$5.9^{+2.1}_{-1.0} (6.5^{+3.1}_{-1.9})$	0.98 (0.92)	0.01 (0.02)
inclusive hard single-le	epton channels				
3-jet (electron)	0.30 (0.28)	6.0 (5.7)	$5.7^{+2.2}_{-1.5}$ $(5.6^{+2.9}_{-1.8})$	0.56 (0.51)	0.48 (0.48)
3-jet (muon)	0.38 (0.37)	7.7 (7.5)	$5.1^{+2.0}_{-1.5}$ $(5.1^{+2.7}_{-1.7})$	0.89 (0.82)	0.13 (0.13)
5-jet (electron)	0.30 (0.29)	6.0 (5.9)	$5.4^{+2.3}_{-1.5}$ $(5.5^{+2.9}_{-1.7})$	0.60 (0.56)	0.43 (0.43)
5-jet (muon)	0.22 (0.21)	4.6 (4.2)	$4.7^{+1.9}_{-1.2}$ $(4.7^{+2.5}_{-1.6})$	0.44 (0.41)	0.50 (0.50)
6-jet (electron)	0.23 (0.22)	4.6 (4.4)	$4.4_{-0.8}^{+1.9} (4.4_{-1.5}^{-1.9})$	0.56 (0.49)	0.50 (0.50)
6-jet (muon)	0.15 (0.12)	3.0 (2.5)	$4.1_{-1.1}^{+1.3} (3.8_{-1.3}^{+2.3})$	0.13 (0.16)	0.50 (0.50)



Signal Region	D	E-loose	E-medium	E-tight
	MC exp	ected events		
Diboson	2.0	5.5	1.7	0.0
$Z/\gamma^*$ +jets	8.5	19.6	6.3	1.9
W+jets	4.8	23.1	5.2	0.8
$t\bar{t}(+EW) + single top$	5.0	67.3	16.8	1.5
	Fitted back	ground even	ts	
Diboson	$2.0 \pm 2.0$	$5.5 \pm 2.1$	$1.7 \pm 0.8$	-
$Z/\gamma^*$ +jets	$3.8 \pm 2.5$	$12 \pm 7$	$2.9 \pm 2.6$	$0.4 \pm 0.6$
W+jets	$3.3 \pm 2.5$	$18 \pm 7$	$4.9 \pm 2.7$	$0.7 \pm 0.5$
$t\bar{t}(+EW) + single top$	$5.8 \pm 2.1$	$76 \pm 19$	$20 \pm 6$	$1.7 \pm 1.4$
Multi-jets	-	$1.0 \pm 1.0$	-	-
Total bkg	$15 \pm 5$	$113 \pm 21$	$30 \pm 8$	$2.9 \pm 1.8$
Observed	18	166	41	5
$\langle \epsilon \sigma \rangle_{\rm obs}^{95}$ [fb]	0.77	4.55	1.41	0.41
S <sup>95</sup> <sub>obs</sub>	15.5	92.4	28.6	8.3
S <sup>95</sup> <sub>exp</sub>	$13.6^{+5.1}_{-3.5}$	$57.3^{+20.0}_{-14.4}$	$21.4^{+7.6}_{-5.8}$	$6.5^{+3.0}_{-1.9}$
$p_0(Z_n)$	0.32 (0.5)	0.03 (1.9)	0.14 (1.1)	0.22 (0.8)

Signal Region	A-loose	A-medium	<b>B-medium</b>	B-tight	C-medium	C-tight			
	MC expected events								
Diboson	428.6	15.0	4.3	0.0	25.5	0.0			
$Z/\gamma^*$ +jets	2044.4	83.1	20.6	2.3	119.4	2.6			
W+jets	2109.0	58.8	16.4	2.1	88.7	1.0			
$t\bar{t}(+EW) + single top$	785.9	8.2	2.0	0.3	45.9	0.3			
-		Fitted backg	ground events						
Diboson	$430 \pm 190$	$15 \pm 7$	$4.3 \pm 2.0$	-	$26 \pm 11$	-			
$Z/\gamma^*$ +jets	$1870 \pm 320$	$57 \pm 11$	$16 \pm 5$	$0.2 \pm 0.5$	$80 \pm 29$	$0.0^{+0.6}_{-0.0}$			
W+jets	$1540\pm260$	$42 \pm 11$	$10 \pm 4$	$1.6 \pm 1.2$	$55 \pm 18$	$0.7 \pm 0.9$			
$t\bar{t}(+EW) + single top$	$870 \pm 180$	$7.8 \pm 2.8$	$2.2 \pm 2.0$	$0.6 \pm 0.7$	$50 \pm 11$	$0.9 \pm 0.9$			
Multi-jets	$33 \pm 33$	-	$0.1 \pm 0.1$	-	-	-			
Total bkg	$4700\pm500$	$122 \pm 18$	$33 \pm 7$	$2.4 \pm 1.4$	$210 \pm 40$	$1.6 \pm 1.4$			
Observed	5333	135	29	4	228	0			
$\langle \epsilon \sigma \rangle_{\rm obs}^{95} [fb]$	66.07	2.52	0.73	0.33	4.00	0.12			
$S_{obs}^{95}$	1341.2	51.3	14.9	6.7	81.2	2.4			
$S_{exp}^{95}$	$1135.0^{+332.7}_{-291.5}$	$42.7^{+15.5}_{-11.4}$	$17.0^{+6.6}_{-4.6}$	$5.8^{+2.9}_{-1.8}$	$72.9^{+23.6}_{-18.0}$	$3.3^{+2.1}_{-1.2}$			
$p_0(Z_n)$	0.45 (0.1)	0.27 (0.6)	0.50 (0.0)	0.34 (0.4)	0.34 (0.4)	0.50 (0.0)			

### 0L+7-10J+MET

Signal region	8j50			
$M_J^{\Sigma}$ [GeV]	340	420		
Observed events	69	37		
Total events after fit	$75 \pm 19$	$45\pm14$		
Fitted $t\bar{t}$	$17 \pm 11$	$16\pm13$		
Fitted W+jets	$0.8^{+1.3}_{-0.8}$	$0.4^{+0.7}_{-0.4}$		
Fitted others	$5.2^{+4.0}_{-2.5}$	$2.8^{+2.9}_{-1.6}$		
Total events before fit	85	44		
$t\bar{t}$ before fit	27	14		
W+jets before fit	0.8	0.4		
Others before fit	5	2.8		
Multi-jets	$52 \pm 15$	$27 \pm 7$		
$N_{\rm BSM}^{95\%}$ (exp)	40	23		
$N_{\rm BSM}^{95\%}$ (obs)	35	20		
$\sigma_{\text{BSM,max}}^{95\%} \cdot A \cdot \epsilon \text{ (exp) [fb]}$	1.9	1.1		
$\sigma_{\rm BSM,max}^{95\%} \cdot A \cdot \epsilon$ (obs) [fb]	1.7	1.0		
$p_0$	0.60	0.7		

Signal region	9j	50	10j50			
$M_J^{\Sigma}$ [GeV]	340	420	340	420		
Observed events	13	9	1	1		
Total events	$17\pm7$	$11 \pm 5$	$3.2^{+3.7}_{-3.2}$	$2.2 \pm 2.$		
tī	$5\pm 4$	$3.4^{+3.6}_{-3.4}$	$0.8^{+0.8}_{-0.8}$	$0.6^{+0.9}_{-0.6}$		
W+jets	_	-	-	_		
Others	$0.58\substack{+0.54\\-0.33}$	$0.39\substack{+0.32\\-0.30}$	$0.12\pm0.12$	$0.06 \pm 0.$		
Multi-jets	$12 \pm 4$	$7.0 \pm 2.3$	$2.3^{+3.6}_{-2.3}$	$1.6^{+1.8}_{-1.6}$		
$N_{\rm BSM}^{95\%}~({\rm exp})$	13	11	5	5		
$N_{\rm BSM}^{95\%}$ (obs)	11	10	4	4		
$\sigma_{\rm BSM,max}^{95\%} \cdot A \cdot \epsilon ~({\rm exp})~[{\rm fb}]$	0.7	0.5	0.23	0.23		
$\sigma_{\rm BSM,max}^{95\%} \cdot A \cdot \epsilon ~{\rm (obs)}~{\rm [fb]}$	0.5	0.5	0.2	0.2		
$p_0$	0.7	0.6	0.8	0.7		

Signal region		8j50			10j50		
<i>b</i> -jets	0	1	$\geq 2$	0	1	$\geq 2$	—
Observed events	40	44	44	5	8	7	3
Total events after fit	$35 \pm 4$	$40 \pm 10$	$50 \pm 10$	$3.3 \pm 0.7$	$6.1 \pm 1.7$	$8.0\pm2.7$	$1.37\pm0.35$
Fitted $t\bar{t}$	$2.7\pm0.9$	$11.8\pm3.0$	$23.0\pm5.0$	$0.36\pm0.18$	$1.5 \pm 0.5$	$3.2\pm1.1$	$0.06^{+0.09}_{-0.06}$
Fitted W+jets	$2.0^{+2.6}_{-2.0}$	$0.62^{+0.81}_{-0.62}$	$0.20^{+0.28}_{-0.20}$	-	$0.24^{+0.65}_{-0.24}$	_	-
Fitted others	$2.9^{+1.8}_{-1.8}$	$1.7^{+1.5}_{-1.2}$	$2.8^{+2.3}_{-2.0}$	$0.03\pm0.03$	$0.38\pm0.25$	$0.40^{+0.60}_{-0.24}$	$0.08\pm0.08$
Total events before fit	36	48	59	3.4	6.6	8.9	1.39
$t\bar{t}$ before fit	3.5	15	30	0.41	1.8	4	0.08
W+jets before fit	2.9	1.0	0.29	-	0.40	-	-
Others before fit	2.4	1.8	2.8	0.03	0.34	0.4	0.08
Multi-jets	$27 \pm 3$	$30 \pm 10$	$26\pm10$	$3.0\pm0.6$	$4.0\pm1.4$	$4.4\pm2.2$	$1.23\pm0.32$
$N_{\rm BSM}^{95\%}$ (exp)	16	23	26	5	7	8	4
$N_{\rm BSM}^{95\%}$ (obs)	20	23	22	7	9	7	6
$\sigma_{\text{BSM,max}}^{95\%} \cdot A \cdot \epsilon \text{ (exp) [fb]}$	0.8	1.2	1.3	0.26	0.36	0.40	0.19
$\sigma_{\rm BSM,max}^{95\%} \cdot A \cdot \epsilon \text{ (obs) [fb]}$	0.97	1.1	1.1	0.34	0.43	0.37	0.29
$p_0$	0.24	0.5	0.7	0.21	0.28	0.6	0.13

Signal region		7j80		8j80				
b-jets	0	1	$\geq 2$	0	1	$\geq 2$		
Observed events	12	17	13	2	1	3		
Total fitted events	$11.0\pm2.2$	$17 \pm 6$	$25 \pm 10$	$0.9\pm0.6$	$1.5 \pm 0.9$	$3.3 \pm 2.$		
Fitted $t\bar{t}$	$0.00^{+0.26}_{-0.00}$	$5.0 \pm 4.0$	$12 \pm 9$	$0.10^{+0.14}_{-0.10}$	$0.32^{+0.67}_{-0.32}$	$1.5^{+1.9}_{-1.5}$		
Fitted W+jets	$0.07^{+0.38}_{-0.07}$	$0.29^{+0.37}_{-0.29}$	-	-	-	-		
Fitted others	$1.9^{+1.1}_{-0.9}$	$0.71^{+0.31}_{-0.25}$	$2.6^{+1.7}_{-1.1}$	$0.02\pm0.02$	$0.02\pm0.02$	$0.32^{+0.3}_{-0.2}$		
Total events before fit	11.7	16	23	0.8	1.8	3.3		
$t\bar{t}$ before fit	0.34	4	10	0.08	0.6	1.5		
W+jets before fit	0.46	0.29	-	-	-	-		
Others before fit	1.8	0.89	3.0	0.02	0.02	0.35		
Multi-jets	$9.1 \pm 1.6$	$11 \pm 4$	$10 \pm 4$	$0.75\pm0.56$	$1.2\pm0.5$	$1.4 \pm 1.$		
$N_{\rm BSM}^{95}$ (exp)	10	17	14	4	4	6		
$N_{\rm BSM}^{95}$ (obs)	10	16	12	5	3.5	6		
$\sigma_{\text{BSM,max}}^{95\%} \cdot A \cdot \epsilon \text{ (exp) [fb]}$	0.5	0.8	0.7	0.18	0.18	0.31		
$\sigma_{\text{BSM,max}}^{95\%} \cdot A \cdot \epsilon \text{ (obs) [fb]}$	0.5	0.8	0.6	0.24	0.17	0.31		
$p_0$	0.5	0.6	0.8	0.19	0.6	0.5		

#### A. Koutsman

### **RESULTS - TRIMMED**

- No significant excess in any signal region (too much to discuss now) ٠
- Data and estimated backgrounds used to set model-independent limits on visible BSM cross section ٠
  - No signal model used, in contrast to model interpretations (next) •
  - $\sigma$ (vis) < 0.12 fb (range between 0.12 66.07 fb) •
    - $\sigma(vis) = \sigma(BSM) \times Acceptance \times efficiency$

Total bkg Observed

 $\langle \epsilon \sigma \rangle_{\rm obs}^{95}$  [fb]  $p_0(Z_n)$ 

p0 = p(s=0) = p-value of background-only hypothesis •



			i	nclusive hard	d single-lepto	n		Signal channel	$\langle \epsilon \sigma \rangle_{\rm obs}^{95}$ [fb]	p(s=0)
		3-jet		5-jet		6-j	et	inclusive hard single-lepton channels		
		electron	muon	electron	muon	electron	muon	3-iet (electron)	0.30 (0.28)	- 0.48(0.48)
	Observed events	4	5	4	2	2	0	3-jet (muon)	0.38 (0.37)	0.13 (0.13)
	Fitted healtenound events	20+10	27.00	26 + 10	25 + 0.8	20+07	17.06	5-jet (electron)	0.30 (0.29)	0.43 (0.43)
	Filled background events	$5.9 \pm 1.0$	$2.7 \pm 0.9$	$3.0 \pm 1.0$	$2.3 \pm 0.8$	$2.0 \pm 0.7$	$1.7 \pm 0.0$	5-jet (muon)	0.22 (0.21)	0.50 (0.50)
			50	oft single len	ton		soft dimuon	6-jet (electron)	0.23 (0.22)	0.50 (0.50)
			3-iet	on single-lep	5-iet		2-iet	6-jet (muon)	0.15 (0.12)	0.50 (0.50)
			5 900		5 јес			soft single-lepton cha	nnels	
	Observed events		7		9		7	3-jet	0.40 (0.39)	0.36 (0.31)
	Fitted background events		56 + 16		148+37		16 + 10	5-jet	0.35 (0.33)	0.50 (0.50)
			5.0 ± 1.0		14.0 ± 5.7		1.0 ± 1.0	soft dimuon channel	0.57 (0.54)	0.01 (0.02)
Sign	hal Region A-loose	A-medium B-m	edium B	-tight C-n	nedium	C-tight	Signal Region	D	E-loose E-m	edium E-1



A-loose	A-medium	B-medium	B-tight	C-medium	C-tight	Signal Region	D	E-loose	E-medium	E-tight
$4700\pm500$	$122 \pm 18$	$33 \pm 7$	$2.4 \pm 1.4$	$210 \pm 40$	$1.6 \pm 1.4$	Total bkg	15 ± 5	$113 \pm 21$	30 ± 8	2.9 ± 1.8
5333	135	29	4	228	0	Observed	18	166	41	5
66.07	2.52	0.73	0.33	4.00	0.12	$\langle \epsilon \sigma \rangle_{\rm abs}^{95}$ [fb]	0.77	4.55	1.41	0.41
0.45 (0.1)	0.27 (0.6)	0.50 (0.0)	0.34 (0.4)	0.34 (0.4)	0.50 (0.0)	$p_0(Z_n)$	0.32 (0.5)	0.03 (1.9)	0.14 (1.1)	0.22 (0.8)



Signal region	8j50			
$M_J^{\Sigma}$ [GeV]	340	420		
Observed events	69	37		
Total events after fit	$75 \pm 19$	$45\pm14$		
$\sigma_{\mathrm{BSM,max}}^{95\%} \cdot A \cdot \epsilon \text{ (obs) [fb]}$	1.7	1.0		
$p_0$	0.60	0.7		

Signal region	9j	9j50 10j50			
$M_J^{\Sigma}$ [GeV]	340 420		340	420	
Observed events	13	9	1	1	
Total events	$17 \pm 7$	$11\pm5$	$3.2^{+3.7}_{-3.2}$	$2.2\pm2.0$	
$\sigma_{\rm BSM,max}^{95\%} \cdot A \cdot \epsilon \text{ (obs) [fb]}$	0.5	0.5	0.2	0.2	
$p_0$	0.7	0.6	0.8	0.7	

Signal region	8j50				10j50		
<i>b</i> -jets	0	1	$\geq 2$	0	1	$\geq 2$	
Observed events	40	44	44	5	8	7	3
Total events after fit	$35 \pm 4$	$40 \pm 10$	$50 \pm 10$	$3.3 \pm 0.7$	$6.1\pm1.7$	$8.0\pm2.7$	$1.37 \pm 0.35$
$\sigma_{\rm BSM,max}^{95\%} \cdot A \cdot \epsilon \text{ (obs) [fb]}$	0.97	1.1	1.1	0.34	0.43	0.37	0.29
$p_0$	0.24	0.5	0.7	0.21	0.28	0.6	0.13

Signal region		7j80		8j80			
<i>b</i> -jets	0	1	$\geq 2$	0	1	$\geq 2$	
Observed events	12	17	13	2	1	3	
Total fitted events	$11.0 \pm 2.2$	$17 \pm 6$	$25 \pm 10$	$0.9 \pm 0.6$	$1.5 \pm 0.9$	$3.3 \pm 2.2$	
$\sigma_{\rm BSM,max}^{95\%} \cdot A \cdot \epsilon \text{ (obs) [fb]}$	0.5	0.8	0.6	0.24	0.17	0.31	
$p_0$	0.5	0.6	0.8	0.19	0.6	0.5	

A. Koutsman