# Searches for squarks and gluinos with the ATLAS detector

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### On behalf of the ATLAS experiment

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17/02/15







ATLAS: Many searches, various final states, numerous models - limits around 1 TeV



# Overview



**ATLAS:** Many searches, various final states, numerous models - <u>limits around 1 TeV</u> **Here:** Focus on three recent searches, spanning range of  $\tilde{q}$  and  $\tilde{g}$  analyses



Squark / Gluino mass



LSP mass

# Overview



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- arXiv: <u>1501.03555</u> [hep-ex], submitted to JHEP
- Many models targeted
  - Gluino  $(\tilde{g})$  and squark  $(\tilde{q})$  production
  - Decays via charginos  $(\tilde{\chi}_1^{\pm})$  and sleptons  $(\tilde{l}) \rightarrow$  leptons in final state
- Four regions, 1 & 2 leptons (decay chain length), soft and hard (mass splittings)
  - Soft:  $E_{\mathrm{T}}^{\mathrm{miss}}$  trigger,  $p_{T}^{\ell} < 25\,\mathrm{GeV}$
  - Hard: Combined  $\ell + E_{\mathrm{T}}^{\mathrm{miss}} \left( + \mathrm{jet} \right)$  triggers







 $1/2 \ \ell$  + jets +  $E_{\mathrm{T}}^{\mathrm{miss}}$ , Mega jets



- Discrimination from  $N_{\rm jets}$ ,  $E_{\rm T}^{\rm miss}$ ,  $m_T$ ,  $m_{\rm eff}$ , topological information
- $m_T = \sqrt{2p_T^{\ell} E_{\mathrm{T}}^{\mathrm{miss}} \left(1 \cos[\Delta \phi(\vec{\ell}, \mathbf{p}_T^{\mathrm{miss}})]\right)}$

• 
$$m_{\text{eff}} = E_{\text{T}}^{\text{miss}} + \sum_{i=1}^{N_{\text{jets}}} p_{T,i}^{\text{jet}} \left( + \sum_{i=1}^{N_{\ell}} p_{T,i}^{\ell} \right)$$



 $1/2~\ell$  + jets +  $E_{
m T}^{
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- Split event into two 'mega jets'



• Exploit symmetry to approximate rest frame - '*R*-frame': '<u>Razor variables</u>'



• Discrimination from  $N_{\rm jets}$ ,  $E_{\rm T}^{\rm miss}$ ,  $m_T$ ,  $m_{\rm eff}$ , topological information

• 
$$m_T = \sqrt{2p_T^{\ell} E_T^{\text{miss}} (1 - \cos[\Delta \phi(\vec{\ell}, \mathbf{p}_T^{\text{miss}})])}$$

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 Exploit symmetry to approximate rest frame - '*R*-frame': '<u>Razor variables</u>'



• 
$$M'_R = \sqrt{(j_{1,E} + j_{2,E})^2 - (j_{1,L} + j_{2,L})^2}$$

- E: Energy in R-frame
- L: Longitudinal momentum

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SM backgrounds controlled with semi data-driven estimate







- Interpret results in a variety of models
- Here:  $\tilde{g}\tilde{g}, \tilde{g} 
  ightarrow qqW \tilde{\chi}_1^0$





- Soft lepton regions contribute to improved sensitivity in compressed regions
- Significant improvement over 2011 results



# Monophoton, Overview





- arXiv: <u>1411.1559</u> [hep-ex], PRD 91, 012008 (2015)
- Compressed spectra ( $\tilde{q}$  and  $\tilde{\chi}_1^0$  close in mass)  $\Rightarrow$  soft decay products, low  $E_{\rm T}^{\rm miss}$



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- ISR photon boosts system  $\Rightarrow$  higher  $E_{\rm T}^{\rm miss}$



# Monophoton, Overview





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- ${\scriptstyle \bullet }$  Veto leptons and >1 jet
- Background  $W\gamma$  (15%) and  $Z\gamma$  (70%) normalized in lepton CRs



# Monophoton, Results



Process	Event yield
$Z(\rightarrow \nu\nu) + \gamma$	$389\pm36\pm10$
$W(\rightarrow \ell \nu) + \gamma$	$82.5 \pm 5.3 \pm 3.4$
$W/Z + \text{jet}, t\bar{t}, \text{diboson}$	$83\pm2\pm28$
$Z(\to \ell\ell) + \gamma$	$2.0\pm0.2\pm0.6$
$\gamma + \text{jet}$	$0.4^{+0.3}_{-0.4}$
Total background	$557\pm36\pm27$
Data	521

Systematic uncertainties  $\sim 15\%$ 

- CR statistics (6%)
- $e \rightarrow \gamma$  mis-ID (5%)



- Best exclusion along 'diagonal'
- Also sets limits for DM and more general models







- Inclusive  $\tilde{q}$  searches weaker if only one light  $\tilde{q}$ :  $\sigma/8$
- In MSSM squarks can mix
  - ${\ensuremath{\, \bullet }}$  Weak flavour physics constraints on  ${\ensuremath{\, t }} {\ensuremath{\, c }}$  mixing
- $\bullet\,$  Charm jet tagging gives improved sensitivity to  $\tilde{c}$
- First dedicated search for scalar charm quark







- Inclusive  $\tilde{q}$  searches weaker if only one light  $\tilde{q}$ :  $\sigma/8$
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  - $\bullet\,$  Weak flavour physics constraints on  ${\tilde t}-{\tilde c}\,$  mixing
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arXiv: <u>1501.01325</u> [hep-ex], accepted by PRL (this morning!)

Simplified model  $ilde{c} 
ightarrow c ilde{\chi}_1^0$ 



- 2 high- $p_{\rm T}$  c-jets
- High  $E_{\mathrm{T}}^{\mathrm{miss}}$
- No leptons



# Scalar charm, Charm tagging





- JetFitterCharm impact parameter and secondary vertex
- c-jets occupy middle ground between b-jets and light-jets
- Image from <u>here</u>



# Scalar charm, Charm tagging II



### 2-variable cut on $P_c$ , $P_b$ , $P_{light}$ , <u>ATL-PHYS-PUB-2015-001</u>, <u>more information</u>





# Scalar charm, Charm tagging II



### 2-variable cut on P<sub>c</sub>, P<sub>b</sub>, P<sub>light</sub>, <u>ATL-PHYS-PUB-2015-001</u>, more information



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Scalar charm, Results





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Run I:

- Diverse and comprehensive range of SUSY searches for squarks and gluinos
- 'Gaps' left by more general searches systematically filled
  - Here:  $1/2 \ \ell + \text{jets} + E_{\text{T}}^{\text{miss}}$ , monophoton, scalar charm

Run II:

- Preparation in earnest, big increase in production cross-sections at 13 TeV
- First results will be for inclusive searches
  - Less sensitive to larger systematics of early data
  - $\bullet~\mbox{Probing highest masses} \Rightarrow \mbox{biggest cross-section boost} \Rightarrow \mbox{fastest gains}$
- Let's hope for a discovery this time next year!





# BONUS SLIDES

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14 / 13



ATLAS SUSY



ATLAS Preliminary

 $\sqrt{s} = 7.8 \text{ TeV}$ 

### Full details at ATLAS SUSY public results page

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

Status: Feb 2015

	Model	$e, \mu, \tau, \gamma$	Jets	$E_{\mathrm{T}}^{\mathrm{miss}}$	∫£ dt[fb	<sup>1</sup> ] Mass limit	Reference
Inclusive Searches	$ \begin{array}{l} \text{MSUGRA/CMSSM} \\ \bar{q}\bar{q}, \bar{q} \rightarrow q \xi_1^0 \\ \bar{q}\bar{q}r, \bar{q} \rightarrow q \xi_1^0 \\ (\text{compressed}) \\ \bar{g}\bar{x}, \bar{x} \rightarrow q \xi_1^0 \\ \bar{x}\bar{x}, \bar{x} \rightarrow q \xi_1^0 \\ \bar{x}\bar{x}, \bar{x} \rightarrow q \xi_1^0 \\ \bar{x}\bar{x}, \bar{x} \rightarrow q \xi_1^0 \\ (\text{MSB} (I, \text{MSP}) \\ \text{GGM} (Ni, \text{SP}) \\ \text{GGM} (vino \text{NLSP}) \\ \text{GGM} (vino \text{NLSP} (vino \text{SP}) \\ \text{GGM} (vino \text{SP} (vino \text{SP}) \\ \text{GGM} (vino \text{SP} (vino \text{SP} (vino \text{SP}) \\$	$\begin{array}{c} 0 \\ 0 \\ 1 \gamma \\ 0 \\ 1 e, \mu \\ 2 e, \mu \\ 1 \cdot 2 \tau + 0 \cdot 1 \ell \\ 2 \gamma \\ 1 e, \mu + \gamma \\ \gamma \\ 2 e, \mu (2) \end{array}$	2-6 jets 2-6 jets 0-1 jet 2-6 jets 3-6 jets 0-3 jets 0-2 jets -	Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20 20 20.3 20.3 20.3	4.1 1.7 TeV m(j)-m(j) 5.250 GeV m(j)-m(2 <sup>m</sup> ga, i)-m(2 <sup>m</sup> ga, i) 5.250 GeV m(j)-GeV m(j)-GeV m(j)-GeV m(j) 5.217 EV m(j)-GeV	1405.7875 1405.7875 1411.1559 1405.7875 1501.03555 1501.03555 1501.03555 1501.03555 1407.0603 ATLAS-CONF-2014-001 ATLAS-CONF-2014-167
3 <sup>rd</sup> gen. <u>§</u> med.	$\begin{array}{c} \text{Gravitio LSP} \\ \bar{g} \rightarrow b \bar{b} \bar{k}_{1}^{0} \\ \bar{g} \rightarrow \bar{t} \bar{k}_{1}^{0} \\ \bar{g} \rightarrow \bar{t} \bar{k}_{1}^{0} \\ \bar{g} \rightarrow b \bar{t} \bar{k}_{1}^{1} \end{array}$	0 0 0-1 e, µ 0-1 c, µ	mono-jet 3 b 7-10 jets 3 b 3 b 3 b	Yes Yes Yes Yes Yes	20.3 20.1 20.3 20.1 20.1 20.1	p <sup>12</sup> costs         865 GeV         m(c)>1.5 × 10 <sup>4</sup> eV m(t)=15 TeV           2         1.25 TeV         m(c) <sup>2</sup> /1,400 GeV           2         1.31 TeV         m(c)/1,400 GeV           2         1.34 TeV         m(c)/1,400 GeV           2         1.34 TeV         m(c)/1,400 GeV	1502.01518 1407.0600 1308.1841 1407.0600 1407.0600
3 <sup>rd</sup> gen. squarks direct production	$\begin{array}{l} b_1 b_1, b_1 \rightarrow b \tilde{\chi}_1^0 \\ b_1 b_1, b_1 \rightarrow \delta \tilde{\chi}_1^+ \\ \bar{\eta}_1 \tilde{\eta}_1, \bar{\eta}_1 \rightarrow b \tilde{\chi}_1^+ \\ \bar{\eta}_1 \tilde{\eta}_1, \bar{\eta}_1 \rightarrow b \tilde{\chi}_1^0 \\ \bar{\eta}_1 \tilde{\eta}_1, \bar{\eta}_1 \rightarrow \delta \tilde{\chi}_1^0 \\ \bar{\eta}_1 \tilde{\eta}_1, \bar{\eta}_1 \rightarrow \delta \tilde{\chi}_1^0 \\ \bar{\eta}_1 \tilde{\eta}_1, \bar{\eta}_1 \rightarrow \delta \tilde{\chi}_1^0 \\ \bar{\eta}_1 \tilde{\eta}_1 (n 1 n 2 n 2 n 2 n 2 n 2 n 2 n 2 n 2 n 2 $	0 $2 e, \mu$ (SS) $1-2 e, \mu$ $2 e, \mu$ $0-1 e, \mu$ $2 e, \mu$ (Z) $3 e, \mu$ (Z)	2 b 0-3 b 1-2 b 0-2 jets 1-2 b nono-jet/c-1 1 b 1 b	Yes Yes Yes Yes tag Yes Yes Yes	20.1 20.3 4.7 20.3 20 20.3 20.3 20.3	δ.         100-250 GeV         m(ζ <sup>2</sup> ), 490 GeV           δ.         125-840 GeV         m(ζ <sup>2</sup> ), 2-2m(ζ <sup>2</sup> ), δ.         m(ζ <sup>2</sup> ), 2-2m(ζ <sup>2</sup> ), 4,         m(ζ <sup>2</sup> ), 2-2m(ζ <sup>2</sup> ), 4, <td>1308.2631 1404.2500 1209.2102, 1407.0583 1403.4853, 1412.4742 1407.0583,1406,1122 1407.0608 1403.5222 1403.5222</td>	1308.2631 1404.2500 1209.2102, 1407.0583 1403.4853, 1412.4742 1407.0583,1406,1122 1407.0608 1403.5222 1403.5222
Other	Scalar charm, $\bar{c} \rightarrow c \bar{\chi}_1^0$ $\sqrt{s} = 7 \text{ TeV}$ full data	0 $\sqrt{s} = 8$ TeV partial data	2c $\sqrt{s} =$ full	Yes 8 TeV data	20.3 10	<del>ک 480 GeV (</del> ۳۵۲) -۱ 1 Mass scale [TeV]	1501.01325

\*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.



ATLAS SUSY

![](_page_26_Picture_2.jpeg)

ATLAS Preliminary

 $\sqrt{s} = 7.8 \text{ TeV}$ 

### Full details at ATLAS SUSY public results page

 $1/2 \ \ell$  + jets +  $E_{\rm T}^{\rm miss}$ , monophoton, <u>scalar charm</u>

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Status: Feb 2015

	Model	$e, \mu, \tau, \gamma$	Jets	$E_{\rm T}^{\rm miss}$	∫£ dt[fb	Mass limit		Reference
	MSUGRA/CMSSM $\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_{1}^{0}$	0	2-6 jets 2-6 jets	Yes Yes	20.3 20.3	4. ž 1.7 Te		1405.7875 1405.7875
Se	$\bar{q}\bar{q}\gamma, \bar{q} \rightarrow q\tilde{\chi}_{1}^{0}$ (compressed)	1γ	0-1 jet	Yes	20.3	9 250 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0) = m(c)$	1411.1559
-Ř	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q \tilde{q} \tilde{\chi}_{1}^{0}$	0	2-6 jets	Yes	20.3	ž 1.33 TeV	m({t_1^0})=0 GeV	1405.7875
au	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq \tilde{\chi}_{1}^{\pm} \rightarrow qq W^{\pm} \tilde{\chi}_{1}^{0}$	1 e,µ	3-6 jets	Yes	20	ž 1.2 TeV	$m(\tilde{\chi}_{1}^{0}) < 300 \text{ GeV}, m(\tilde{\chi}^{+}) = 0.5(m(\tilde{\chi}_{1}^{0}) + m(\tilde{g}))$	1501.03555
S	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_{1}^{0}$	2 e, µ	0-3 jets		20	ž 1.32 TeV	m( $\hat{\chi}_{1}^{0}$ )=0 GeV	1501.03555
9	GMSB ( <i>t</i> NLSP)	1-2 T + 0-1 l	0-2 jets	Yes	20.3	ž 1.6 TeV	tanβ >20	1407.0603
is i	GGM (bino NLSP)	2γ	-	Yes	20.3	ž 1.28 TeV	m(k <sup>0</sup> <sub>1</sub> )>50 GeV	ATLAS-CONF-2014-001
S.	GGM (wino NLSP)	1 e, μ + γ	-	Yes	4.8	ž 619 GeV	m(k <sup>0</sup> <sub>1</sub> )>50 GeV	ATLAS-CONF-2012-144
5	GGM (higgsino-bino NLSP)	γ	1 <i>b</i>	Yes	4.8	ž 900 GeV	m({t1})>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, µ (Z)	0-3 jets	Yes	5.8	ž 690 GeV	m(NLSP)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	t Yes	20.3	F <sup>1/2</sup> scale 865 GeV	$m(\tilde{G}) > 1.8 \times 10^{-4} \text{ eV}, m(\tilde{g}) = m(\tilde{q}) = 1.5 \text{ TeV}$	1502.01518
d	$\tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_{1}^{0}$	0	3 b	Yes	20.1	ž 1.25 TeV	m({{z}_{1}^{0}})<400 GeV	1407.0600
28	$\bar{g} \rightarrow t \bar{t} \bar{\chi}_1^0$	0	7-10 jets	Yes	20.3	ž 1.1 TeV	m( $\hat{\chi}_1^0$ ) <350 GeV	1308.1841
Ξ°°Ę	$\bar{g} \rightarrow t \bar{t} \chi_1^0$	0-1 e, µ	3 b	Yes	20.1	ž 1.34 TeV	m( $\hat{\ell}_1^0$ )<400 GeV	1407.0600
ico 100	$\tilde{g} \rightarrow b \tilde{\iota} \tilde{\chi}_{1}^{+}$	0-1 e, µ	3 b	Yes	20.1	ž 1.3 TeV	m({21/1})<300 GeV	1407.0600
	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$	0	2 b	Yes	20.1	b <sub>1</sub> 100-620 GeV	m({\vec{k}_{1}^{0}})<90 GeV	1308.2631
žē	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow t \tilde{\chi}_1^{\pm}$	2 e, µ (SS)	0-3 b	Yes	20.3	δ <sub>1</sub> 275-440 GeV	$m(\tilde{\chi}_{1}^{*})=2 m(\tilde{\chi}_{1}^{0})$	1404.2500
2 2	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow b \tilde{\chi}_1^{\pm}$	1-2 e, µ	1-2 b	Yes	4.7	ži 110-167 GeV 230-460 GeV	$m(\hat{\chi}_{1}^{n}) = 2m(\hat{\chi}_{1}^{0}), m(\hat{\chi}_{1}^{0})=55 \text{ GeV}$	1209.2102, 1407.0583
SB	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W b \tilde{\chi}_1^0 \text{ or } t \tilde{\chi}_1^0$	2 e, µ	0-2 jets	Yes	20.3	<i>ī</i> <sub>1</sub> 90-191 GeV 215-530 GeV	m( $\hat{x}_{1}^{0}$ )=1 GeV	1403.4853, 1412.4742
εà	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$	0-1 e, µ	1-2 b	Yes	20	Ĩ1 210-640 GeV	m( $\hat{x}_{1}^{0}$ )=1 GeV	1407.0583,1406.1122
SC B	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow c \tilde{\chi}_1^0$	0 m	iono-jet/c-l	tag Yes	20.3	<i>i</i> <sub>1</sub> 90-240 GeV	m(r <sub>1</sub> )-m(t <sup>0</sup> <sub>1</sub> )<85 GeV	1407.0608
2.4	<i>ī</i> <sub>1</sub> <i>ī</i> <sub>1</sub> (natural GMSB)	2 e, µ (Z)	1 b	Yes	20.3	<i>i</i> <sub>1</sub> 150-580 GeV	m(x <sup>0</sup> <sub>1</sub> )>150 GeV	1403.5222
e, 0	$\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 e, µ (Z)	1 b	Yes	20.3	Ĩ2 290-600 GeV	m({\$\vec{k}_1^0})<200 GeV	1403.5222
Other	Scalar charm, $\tilde{c} \rightarrow c \tilde{\chi}_1^0$	0	2 c	Yes	20.3	č 490 GeV	m(x <sup>0</sup> <sub>1</sub> )<200 GeV	1501.01325
	$\sqrt{s} = 7 \text{ TeV}$ full data	$\sqrt{s}$ = 8 TeV partial data	$\sqrt{s} = full$	8 TeV data	1	-1 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 or theoretical signal cross section uncertainty.

![](_page_27_Picture_0.jpeg)

# Squarks and gluinos

![](_page_27_Picture_2.jpeg)

- SUSY has 12  $\tilde{q}$  two for each SM quark
- Usually treat 3rd generation separately, i.e.  $m_{\tilde{t}_{1,2}}, m_{\tilde{b}_{1,2}}, m_{\tilde{q}}: q = u, d, s, c$
- 'Traditional' squark and gluino searches:  $\tilde{g}$  and first two generation  $\tilde{q}$
- Highest cross sections for SUSY production at a *pp* machine
- Signatures:  $\tilde{g} \rightarrow \tilde{q}q \rightarrow q \tilde{\chi}_1^0 q$ : high  $E_{\mathrm{T}}^{\mathrm{miss}}$ , jets, (leptons)

![](_page_27_Figure_8.jpeg)

![](_page_28_Picture_0.jpeg)

# $1/2~\ell+{ m jets}+{\it E}_{ m T}^{ m miss}$ , Signal models

![](_page_28_Picture_2.jpeg)

![](_page_28_Figure_3.jpeg)

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![](_page_29_Picture_1.jpeg)

More details on public page

Model	Soft		Hard	
	single-lepton	dimuon	single-lepton	dilepton
mSUGRA/CMSSM			$\checkmark$	
bRPV mSUGRA/CMSSM			$\checkmark$	
nGM			$\checkmark$	
NUHMG			$\checkmark$	
mUED		$\checkmark$		√
$\tilde{g}\tilde{g}$ production, $\tilde{g} \to tc\tilde{\chi}_1^0$			$\checkmark$	
$\tilde{g}\tilde{g}$ production, $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$			$\checkmark$	
$\tilde{g}\tilde{g}$ production, $\tilde{g} \to qqW\tilde{\chi}_1^0$	$\checkmark$		$\checkmark$	
$\tilde{q}\tilde{q}$ production, $\tilde{q} \to qW\tilde{\chi}_1^0$	$\checkmark$		$\checkmark$	
$\tilde{g}\tilde{g}$ production, $\tilde{g} \to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$			$\checkmark$	$\checkmark$
$\tilde{q}\tilde{q}$ production, $\tilde{q} \to q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$				$\checkmark$
$\tilde{g}\tilde{g}$ production, $\tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$			$\checkmark$	

![](_page_30_Picture_0.jpeg)

R-frame calculation details here

Razor variables:

$$\begin{split} M_{R}' &= \sqrt{(j_{1,E} + j_{2,E})^{2} - (j_{1,L} + j_{2,L})^{2}} \\ M_{T}^{R} &= \sqrt{\frac{|\boldsymbol{p}_{T}^{\text{miss}}|(|\vec{j}_{1,T}| + |\vec{j}_{2,T}|) - \boldsymbol{p}_{T}^{\text{miss}} \cdot (\vec{j}_{1,T} + \vec{j}_{2,T})}{2}} \\ R &= \frac{M_{T}^{R}}{M_{R}'} \end{split}$$

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**ATLAS**  $1/2 \ell$  + jets +  $E_{\mathrm{T}}^{\mathrm{miss}}$ , Other exclusion P OXFORD

Full set of exclusion plots on public page; here:  $\tilde{q}$ -  $\tilde{\chi}_1^0$  plane

![](_page_31_Figure_2.jpeg)

![](_page_32_Picture_0.jpeg)

![](_page_32_Picture_2.jpeg)

 $m_{\tilde{q}} =$  200 GeV,  $m_{\tilde{\chi}^0_1} =$  195 GeV; 10,000 events generated; more details on public page

Nominal	9989
Pre-selected:	
1. Trigger	8582
2. Good vertex	8574
3. Cleaning cuts	8213
SR Cuts:	
1. $E_{\rm T}^{\rm miss} > 150 { m ~GeV}$	4131
2. At least one loose photon with $p_{\rm T} > 125 \text{ GeV}( \eta  < 2.37)$	2645
3. The leading photon is tight with $ \eta  < 1.37$	2068
4. The leading photon is isolated	1898
5. $\Delta \phi(\gamma^{\text{leading}}, \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}}) > 0.4$	1887
6. Jet veto: $N_{\rm jet} \leq 1$ and $\Delta \phi({\rm jet}, \boldsymbol{E}_{\rm T}^{\rm miss}) > 0.4$	1219
7. Lepton veto	1188

![](_page_33_Picture_0.jpeg)

![](_page_33_Picture_2.jpeg)

Limits for multiple generic higher-dimensional operators

![](_page_33_Figure_4.jpeg)

![](_page_34_Picture_0.jpeg)

![](_page_34_Picture_2.jpeg)

Plots and tables on public page

- Use  $E_{\mathrm{T}}^{\mathrm{miss}}$  trigger, 20.3fb<sup>-1</sup>
  - Leading jet  $p_{\rm T} > 130 {\rm GeV}$ ,  $E_{\rm T}^{\rm miss} > 150 {\rm GeV}$
- Event Cleaning
- Lepton veto
- Leading two jets *c*-tagged
- Jet 2  $p_{\rm T} > 100 {
  m GeV}$
- $m_{\rm CC}>200{
  m GeV}$
- Three SR:

 $m_{\rm CT} > \{150, 200, 250\}$  GeV

![](_page_34_Figure_13.jpeg)

 $Z + \text{jets} \approx 50\%$  $W + \text{jets} \approx 25\%$  $t\bar{t}$  or single  $t \approx 25\%$ 

![](_page_35_Picture_0.jpeg)

![](_page_35_Picture_2.jpeg)

All control regions: c-tag leading two jets, use single-lepton triggers, relax some cuts for statistics

CRW: Single lepton, 40 GeV  $< m_{\rm T} < 100$  GeV CRZ: OSSF leptons,  $|m_{\ell\ell} - 90$  GeV| < 15 GeV CRT: One *e*, one  $\mu$ CRQCD: Jet smearing method,  $\Delta \phi_{\rm min}(\mathbf{p}_{\rm T}^{\rm miss}, 3 \text{ jets}) < 0.4$ 

![](_page_36_Picture_0.jpeg)

![](_page_36_Picture_2.jpeg)

Cut	Description	Signal regions		Control regions					
		SRs	CRZ CRT		CRW				
1	Trigger	$E_{\mathrm{T}}^{\mathrm{miss}}$	$E_{\rm T}^{\rm miss}$ Single lepton						
2	Event cleaning	Common to all SR and CR							
3	Lepton selection	—	2 SF OS	2 DF OS	1				
Ŭ	Lepton selection	No further	No further $e/\mu$ (after overlap removal) with $p_{\rm T} > 7(6)$ GeV for $e(\mu)$ .						
4	$E_{\mathrm{T}}^{\mathrm{miss}}$	> 150  GeV	—	— > 50 GeV					
	$\vec{p}_{\mathrm{T}}^{\mathrm{miss}}$ + $\vec{p}_{T}^{\mathrm{2leptons}}$	ptons — > 100 GeV —		—	—				
5	Leading jet $p_{\rm T}$	> 130  GeV	> 50  GeV	> 130  GeV					
6	Second jet $p_{\rm T}$	> 100  GeV	> 100 GeV > 50 GeV						
7	c-tagging	leading 2 jets ( $p_{\rm T} > 50$ GeV, $ \eta  < 2.5$ )							
8	$\Delta \phi_{ m min}(ec{p}_{ m T}^{ m miss}$ , 3 jets)	> 0.4	_						
9	$E_{\mathrm{T}}^{\mathrm{miss}}/(E_{\mathrm{T}}^{\mathrm{miss}}+p_{\mathrm{T}}^{\mathrm{2jets}})$	> 0.25	_						
10	Leading lepton $p_T$	—	> 70  GeV	> 25  GeV	> 50  GeV				
11	$m_{ll}$	—	$90 \pm 15 { m ~GeV}$	—					
12	$m_T$		— 40 – 100 G						
13	m <sub>cc</sub>	> 200  GeV	-						
14	$m_{ m CT}$	> 150, 200, 250 GeV	0 GeV — — > 150 GeV						

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![](_page_37_Picture_0.jpeg)

# Scalar charm, Event display

![](_page_37_Picture_2.jpeg)

![](_page_37_Picture_3.jpeg)

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26 / 13

![](_page_38_Picture_0.jpeg)

![](_page_38_Picture_2.jpeg)

### Public note at ATL-PHYS-PUB-2015-001

![](_page_38_Figure_4.jpeg)

![](_page_39_Picture_0.jpeg)

![](_page_39_Picture_2.jpeg)

Algorithm	Variable Name	Description			
	acat	$p_T$ category of jet, divisions [GeV]:			
Kinematic	PT	$15, 25, 35, 50, 80, 120, 200, \infty$			
Rinematic	mcat	η  category of jet, divisions:			
	4	0, 0.7, 1.5, 2.5			
IP3D	$\log(\mathcal{L}_b/\mathcal{L}_{light})$	log ratio between b-jet and light-jet likelihood value			
	$n_{trk}^{SV1}$	Number of tracks matched to the vertex			
SV1	n <sub>2t</sub>	Number of two-track vertices found in the jet			
511	$m_{vx}$	Secondary vertex mass			
	$L/\sigma_L$	Secondary vertex flight-length significance			
	$m_{chain}$	Invariant mass of decay products			
	$S_d^{JF}$	Total vertex flight-length significance			
	$n_{\rm vx}$	Number of reconstructed vertices with $\geq 2$ tracks			
	$n_{trk}^{JF}$	Number of tracks matched to vertices with $\geq 2$ tracks			
IntFitton	n <sub>1t</sub>	Number of single-track vertices			
Jetritter	$L^1_{xy}$	Transverse displacement of the secondary vertex			
	$L_{xy}^{2}$	Transverse displacement of the tertiary vertex			
	$\min \varphi_{trk}$	Minimum track rapidity along jet axis			
	$\langle \varphi_{trk} \rangle$	Mean track rapidity along jet axis			
	$\max \varphi_{trk}$	Maximum track rapidity along jet axis			
SV1, JetFitter	F / F	Ratio of the vertex track energy sum			
(variables input from both)	L <sub>vx</sub> /L <sub>jet</sub>	to the jet track energy sum			

Summary of the variables used by the JetFitterCharm neural network. JetFitterCharm uses a 'charm tuned' variant of the standard JetFitter used by other ATLAS tagging algorithms. The charm tuned JetFitter also adds the variables  $L_{xy}^1$ ,  $L_{xy}^2$ , and  $\varphi_{trk}$ . Note that  $\varphi_{trk}$  is the track rapidity computed with respect to the jet axis.

![](_page_40_Picture_0.jpeg)

![](_page_40_Picture_2.jpeg)

![](_page_40_Figure_3.jpeg)

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![](_page_41_Picture_0.jpeg)

![](_page_41_Picture_2.jpeg)

	Con	trol Reg	ions	Signal Regions, $m_{\rm CT}$ [GeV]			
	CRT	$\operatorname{CRZ}$	CRW	> 150	>200	$>\!250$	
Top	$129\pm11$	$7.3\pm0.8$	$45\pm7$	$7.4 \pm 2.7$	$3.9\pm1.6$	$1.6\pm0.7$	
iop	(124)	(7.1)	(44)	(7.1)	(3.7)	(1.5)	
Z⊥iote	$0.1\pm0.0$	$47\pm7$	$0.1\pm0.1$	$14 \pm 3$	$7.7\pm1.7$	$4.3\pm1.2$	
⊿ – jeta	(0.1)	(43)	(0.1)	(13)	(7.0)	(3.9)	
$W \perp iote$	< 0.1	< 0.1	$15\pm9$	$7.2 \pm 4.5$	$4.1\pm2.6$	$1.9\pm1.2$	
w ⊤jeta	(< 0.1)	(< 0.1)	(16)	(7.4)	(4.2)	(1.9)	
Multijets	—	_	-	$0.3 \pm 0.3$	$0.2\pm0.2$	$0.05\pm0.05$	
Others	$0.1\pm0.1$	$1.4\pm0.8$	$1.3\pm0.8$	$0.5\pm0.3$	$0.4\pm0.3$	$0.4\pm0.3$	
Total	$129\pm11$	$56\pm7$	$62\pm7$	$30\pm 6$	$16\pm3$	$\boldsymbol{8.2 \pm 1.9}$	
Data	129	56	62	19	11	4	

![](_page_42_Picture_0.jpeg)

![](_page_42_Figure_2.jpeg)

![](_page_42_Figure_3.jpeg)

- Using lowest expected  $CL_s$  for three  $m_{CT}$  regions and  $\tilde{t} \rightarrow c \tilde{\chi}_1^0$  c-tagged regions
- Observed band: č xsec varied down / up

• Excludes  $\tilde{c}$  from  $m_{\tilde{c}}=m_{\tilde{\chi}_1^0}$  to  $m_{\tilde{c}}=$  490 GeV and  $m_{\tilde{\chi}_1^0}<$  200 GeV