



### Searches for resonant and non-resonant new phenomena from ATLAS

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### Introduction: Resonant and non-resonant searches

#### **Non-Resonant:**

- Contact interactions can be found • in a non-resonant search.
- Looks for an overall increase in • total number of signal events.
- Can be mistaken for high energy • QCD effects.

#### **Resonant:**

- Mediator particle decays can be found in a resonant search.
- Looks for a narrow or broad peak • on top of a continuum.











### Di-jet searches (resonant 8 TeV)



#### **Event Selection**

- Single jet trigger
- At least two jets in event
- $m_{ii} > 250 \text{ GeV}$
- Rapidity (y) of leading jets < 2.8
- Transverse momentums  $(p_T) > 50 \text{ GeV}$
- $|y^*| = \frac{1}{2} |y_1 y_2| < 0.6$





#### Phenomenological Models (limits [TeV])

Excited quarks, q\*:  $m_{q*} > 4.06$ Color-octet scalars, s8  $m_{s8} > 2.70$ Heavy W' gauge bosons  $m_{W} > 2.45$ Chiral W\* gauge bosons  $m_{W*}$  leptophobic > 1.75 $m_{W*}$  leptophilic > 1.65Quantum black holes  $m_{BH} > 5.66$ 

Phys. Rev. D. 91, 052007 (2015), arXiv:1407.1376 (resonant)







Phys. Rev. Lett. 114, 221802, (2015) arXiv:1504.00357



#### **Event Selection:**

- Single jet trigger
- At least two jets in event
- $m_{ij} > 600 \text{ GeV}$
- Rapidity boost of system:  $|y_B| = \frac{1}{2} |y_1 + y_2| < 1.1$
- $|y^*| = \frac{1}{2} |y_1 y_2| < 1.7$

Scattering angle between two jets:  $\chi \equiv e^{|y_1-y_2|} = e^{2|y^*|}$ 

#### Models:

- Strong gravity
- Contact interactions
  - $\Lambda > 8.1$  TeV (destructive interference)
  - $\Lambda > 12.0$  TeV (constructive interference)



# Di-lepton (resonant)





### <sup>University</sup> of Victoria Di-lepton (non-resonant)





#### **Contact Interactions**

Coupling between  $q_{L,R}$  and  $\ell_{L,R}$ probed for contact interactions

#### Large extra spatial dimensions

The string scale Ms is probed for interference and graviton effects

#### Leptons:

- $m_{\ell\ell} > 80 \text{ GeV}$
- \* Background scaled to data in region  $80 \; GeV \le m_{tt} \le 120 \; GeV$
- Control region for verification  $120 \text{ GeV} < m_{tt} < 400 \text{ GeV}$

#### **Electrons**:

- Di-EM calorimeter clusters trigger
- Shower profile and leakage, tracking quality
- Calorimetric isolation
- Opposite sign

#### QCD@LHC2015

#### $\Lambda > 26.3$ TeV (L-R constructive)

#### $M_s > 5.0$ TeV (HLZ n=3 ADD)

![](_page_5_Figure_19.jpeg)

#### **Muons:**

- Single muon triggers
- Inner detector & Muon Spectrometer quality
- Track isolation
- Opposite sign

#### September 2, 2015

![](_page_6_Figure_0.jpeg)

### Phenomenological Models (limits [TeV])

SSM W' gauge bosons	m <sub>w</sub> > 3.24 TeV
Chiral W* gauge bosons	$m_{W^*}^{>}$ 3.21 TeV

Dark Matter Effective Field Theory (DM EFT): Various M\* limits for different DM masses

#### **Event Selection**

- Single EM or muon trigger
- Electron:  $E_T$  and  $E_T^{miss} > 125 \text{ GeV}$
- Muon:  $p_T$  and  $E_T^{miss} > 45 \text{ GeV}$
- Isolated lepton

$$\mathbf{m}_{\mathrm{T}} \equiv \sqrt{(2\mathbf{p}_{\mathrm{T}} \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos \varphi_{\mathrm{fy}}))}$$

![](_page_6_Figure_10.jpeg)

![](_page_7_Picture_0.jpeg)

## Lepton + jets

![](_page_7_Picture_2.jpeg)

#### **Event Selection**

- Single electron, single muon, and large-radius jet triggers ٠
- Isolated leptons with  $E_T > 25$  GeV (e),  $p_T > 25$  GeV (mu) •
- Transverse mass:  $m_T \equiv \sqrt{(2p_T E_T^{\text{miss}}(1 \cos \phi_{fy}))}$
- $E_{T}^{miss} > 25 \text{ GeV}$ •
- $E_{T}^{miss} + m_{T} > 60 \text{ GeV}$
- **Boosted Topologies** (large-radius jet along with lepton + small jet)
- **Resolved Topologies** • (four small-radius jets individually resolved)

#### $5_{Z'} \times BR(Z' \rightarrow t\bar{t})$ [pb] ATLAS Obs. 95% CL upper limit $10^{3}$ Exp. 95% CL upper limit (pre-fit) √s=8 TeV, 20.3 fb<sup>-1</sup> Exp. 95% CL upper limit (post-fit) Exp. 1 $\sigma$ uncertainty (pre-fit) Exp. 2 $\sigma$ uncertainty (pre-fit) 10 Leptophobic Z'(1.2%) (LO x 1.3) Leptophobic Z'(2%) (LO x 1.3) Leptophobic Z'(3%) (LO x 1.3) 10 10 05 1.5

#### Phenomenological Models (limits [TeV])

- Topcolour-assisted-technicolour  $Z'_{TC2}$  $m_{\tau} > 1.8 \text{ TeV}$
- Bulk RS Kaluza–Klein gluon,  $m_{\sigma KK} > 2.2$  TeV
- Bulk RS Kaluza-Klein graviton, no limits set
- Scalar resonance, no limits set

![](_page_7_Figure_17.jpeg)

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#### OCD@LHC2015

Z' mass [TeV]

arXiv:1505.07018

#### September 2, 2015

![](_page_8_Picture_0.jpeg)

# Di-photon

![](_page_8_Picture_2.jpeg)

Phys. Rev. D 92, 032004 (2015) arXiv:1504.05511

• Randall-Sundrum (RS) Model of extra spacial dimensions, leading to spin-2 gravitons

$$m_{G^*} > 2.66 \text{ TeV} (k/\overline{M}_{Pl} = 0.1)$$
  
 $m_{G^*} > 1.41 \text{ TeV} (k/\overline{M}_{Pl} = 0.01)$ 

- Di-photon trigger
- Calorimetric isolation
- Shower shape quality

![](_page_8_Figure_9.jpeg)

![](_page_8_Figure_10.jpeg)

September 2, 2015 9

![](_page_9_Figure_0.jpeg)

#### Phenomenological Models (limits [TeV])

- QBH model  $M_{th} > 4.6 \text{ TeV}$
- Generic gaussian-shape, exclude  $m_G of 4 \text{ GeV} (5\% \text{ width, visible } \sigma \text{ near } 0.1)$
- Excited-quark model  $m_{q^*} > 3.5 \text{ TeV}$

- One photon and one jet candidate, each with  $p_T > 125 \text{ GeV}$
- Central, isolated photon
- Pseudorapidity  $\Delta \eta = |\eta_{\gamma} \eta_{iet}| > 1.6$

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![](_page_10_Picture_0.jpeg)

# Multi-jets (8 TeV)

JHEP 07 (2015) 032, arXiv:1503.08988

 $H_{T}$  is defined as the scalar sum of  $p_{T}$  of jets in the event

- High  $H_T$  trigger, efficient > 1.2 TeV (> 1.5 TeV used in analysis)
- Three or more central jets with  $p_T > 50 \text{ GeV}$
- SM background estimated by low H<sub>T</sub> region extrapolation through generators PYTHIA 8, Herwig++, and ALPGEN MC
- Black holes and string balls searched for in most sensitive regions

![](_page_10_Figure_8.jpeg)

![](_page_10_Figure_9.jpeg)

![](_page_10_Figure_10.jpeg)

![](_page_11_Figure_0.jpeg)

![](_page_12_Picture_0.jpeg)

## Di-bosons

![](_page_12_Picture_2.jpeg)

![](_page_12_Figure_3.jpeg)

![](_page_13_Picture_0.jpeg)

# New: Run-2 Results

![](_page_13_Picture_2.jpeg)

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2

![](_page_13_Figure_4.jpeg)

![](_page_14_Picture_0.jpeg)

## Di-jets (13 TeV)

![](_page_14_Picture_2.jpeg)

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-042/

![](_page_14_Figure_4.jpeg)

![](_page_14_Picture_5.jpeg)

15

![](_page_15_Picture_0.jpeg)

### Multi-jets (13 TeV)

![](_page_15_Picture_2.jpeg)

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-043/

![](_page_15_Figure_4.jpeg)

![](_page_15_Figure_5.jpeg)

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![](_page_16_Picture_0.jpeg)

# Conclusion

![](_page_16_Picture_2.jpeg)

- Searches through many final states
- No significant excesses in any channels
  - Potential hints of new physics in di-boson channels
  - Very good agreement between data and Monte Carlo shapes in lepton + MET, di-lepton and multi-jets
- Excellent performance ATLAS Run-1
- New opportunities upcoming in Run-2
  - First data analyzed
  - Run-1 sensitivities should hopefully be exceeded by end of 2015

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![](_page_17_Picture_0.jpeg)

### Full Exotics search summary

Limit

![](_page_17_Picture_2.jpeg)

#### ATLAS Exotics Searches\* - 95% CL Exclusion

 $\ell, \gamma$  Jets  $\mathsf{E}^{\text{miss}}_{-}$  ( $\mathcal{L}$  dt[fb<sup>-1</sup>]

Status: July 2015 Model

 $\int \mathcal{L} dt = (4.7 - 20.3) \text{ fb}^{-1}$ 

 $\sqrt{s} = 7, 8 \text{ TeV}$ 

**ATLAS** Preliminary

					<u> </u>		
s Extra dimensions	ADD $G_{KK} + g/q$ ADD non-resonant $\ell\ell$ ADD QBH $\rightarrow \ell q$ ADD QBH $\rightarrow \ell q$ ADD QBH high $N_{trk}$ ADD BH high $\Sigma_{PT}$ ADD BH high multijet RS1 $G_{KK} \rightarrow \ell\ell$ RS1 $G_{KK} \rightarrow \gamma\gamma$ Bulk RS $G_{KK} \rightarrow ZZ \rightarrow qq\ell\ell$ Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\gamma$ Bulk RS $G_{KK} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$ Bulk RS $g_{KK} \rightarrow t\bar{t}$ 2UED / RPP SSM $Z' \rightarrow \ell\ell$	$\begin{array}{c} -\\ 2e, \mu\\ 1e, \mu\\ 2\mu(SS)\\ \ge 1e, \mu\\ -\\ -\\ 2e, \mu\\ 2\gamma\\ 2e, \mu\\ 1e, \mu\\ -\\ 2e, \mu(SS)\\ 2e, \mu\\ 2\gamma\\ 2e, \mu\\ 2\gamma\\ 2e, \mu\\ 2z, \end{array}$		Yes - - - - Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.3	Mo         5.25 TeV         n = 2           Ms         4.7 TeV         n = 3 HLZ           Mth         5.2 TeV         n = 6           Mth         5.82 TeV         n = 6, Mo = 3 TeV, non-rot BH           Mth         5.8 TeV         n = 6, Mo = 3 TeV, non-rot BH           Mth         5.8 TeV         n = 6, Mo = 3 TeV, non-rot BH           Grave mass         2.68 TeV         k/Mp = 0.1           Grave mass         740 GeV         k/Mp = 0.1           W' mass         760 GeV         k/Mp = 1.0           W' mass         500-720 GeV         k/Mp = 1.0           Krk mass         960 GeV         2.2 TeV           Z' mass         2.02 TeV         BR = 0.925	1502.01518 1407.2410 1311.2006 1407.1376 1308.4075 1405.4254 1503.09988 1405.4123 1504.05511 1409.6190 1503.04677 1506.00285 1505.07018 1504.04605 1405.4123 1509.07177
CI Gauge boson	$\begin{array}{l} \text{SSM } \mathcal{W}' \to \ell \nu \\ \text{EGM } \mathcal{W}' \to WZ \to \ell \nu  \ell' \ell' \\ \text{EGM } \mathcal{W}' \to WZ \to qq\ell\ell \\ \text{EGM } \mathcal{W}' \to WZ \to qqqq \\ \text{HVT } \mathcal{W}' \to WH \to \ell \nu bb \\ \text{LRSM } \mathcal{W}_R^{R} \to t\bar{b} \\ \text{LRSM } \mathcal{W}_R^{R} \to t\bar{b} \end{array}$	1 e, μ 3 e, μ 2 e, μ - 1 e, μ 1 e, μ 0 e, μ - 2 e, μ	 2j/1J 2J 2b 2b,0-1j ≥1b,1J 2j 	- Yes - - Yes Yes - -	19.5 20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.3	$W'$ mass       3.24 TeV $W'$ mass       1.52 TeV $W'$ mass       1.52 TeV $W'$ mass       1.59 TeV $W'$ mass       1.34.1.5 TeV $W'$ mass       1.34.1.5 TeV $W'$ mass       1.34.1.5 TeV $W'$ mass       1.34.1.5 TeV $W'$ mass       1.32 TeV $W'$ mass       1.92 TeV $W'$ mass       1.76 TeV $\Lambda$ 12.0 TeV $\Lambda$ 21.6 TeV	1405.77494 1406.4456 1409.6190 1506.00962 1503.08089 1410.4103 1408.0886 1504.00357 1407.2410
MO	Cl uutt EFT D5 operator (Dirac)	2 e, μ (SS) 0 e, μ	$\geq 1 \text{ b}, \geq 1 \text{ j}$ $\geq 1 \text{ j}$	Yes Yes	20.3 20.3	$\Lambda$ 4.3 TeV $ C_{LL}  = 1$ M.         974 GeV         at 90% CL for $m(\chi) < 100$ GeV           M.         974 GeV         at 90% (CL for $m(\chi) < 100$ GeV	1504.04605 1502.01518
ΓØ	Scalar LQ 1 <sup>st</sup> gen Scalar LQ 2 <sup>nd</sup> gen Scalar LQ 3 <sup>rd</sup> gen	2 e 2 μ 1 e,μ	≥ 2 j ≥ 2 j ≥1 b, ≥3 j	- - Yes	20.3 20.3 20.3 20.3	LQ mass         1.05 TeV $\beta = 1$ LQ mass         1.0 TeV $\beta = 1$ LQ mass         640 GeV $\beta = 0$	Preliminary Preliminary Preliminary
Heavy quarks	$ \begin{array}{l} VLQ \ TT \rightarrow Ht + X \\ VLQ \ YY \rightarrow Wb + X \\ VLQ \ BB \rightarrow Hb + X \\ VLQ \ BB \rightarrow Zb + X \\ T_{5/3} \rightarrow Wt \end{array} $	1 e,μ 1 e,μ 1 e,μ 2/≥3 e,μ 1 e,μ		Yes Yes - Yes	20.3 20.3 20.3 20.3 20.3 20.3	T mass         855 GeV         T in (T,B) doublet           Y mass         770 GeV         Y in (B,Y) doublet           B mass         735 GeV         isospin singlet           B mass         755 GeV         B in (B,Y) doublet           T <sub>5/3</sub> mass         840 GeV         B in (B,Y) doublet	1505.04306 1505.04306 1505.04306 1409.5500 1503.05425
Excited fermions	Excited quark $q^* \rightarrow q\gamma$ Excited quark $q^* \rightarrow qg$ Excited quark $b^* \rightarrow Wt$ Excited lepton $\ell^* \rightarrow \ell\gamma$ Excited lepton $v^* \rightarrow \ell W, vZ$	1 γ 1 or 2 e, μ 2 e, μ, 1 γ 3 e, μ, τ	1 j 2 j 1 b, 2 j or 1 j –	- Yes -	20.3 20.3 4.7 13.0 20.3	q* mass         3.5 TeV         only u* and d*, $\Lambda = m(q^*)$ q* mass         4.09 TeV         only u* and d*, $\Lambda = m(q^*)$ b* mass         870 GeV         left-handed coupling           t* mass         2.2 TeV $\Lambda = 2.2$ TeV           v* mass         1.6 TeV $\Lambda = 1.6$ TeV	1309.3230 1407.1376 1301.1583 1308.1364 1411.2921
Other	LSTC $a_T \rightarrow W\gamma$ LRSM Majorana v Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$ Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$ Monotop (non-res prod) Multi-charged particles Magnetic monopoles	$1 e, \mu, 1 \gamma  2 e, \mu  2 e, \mu (SS)  3 e, \mu, \tau  1 e, \mu $	2 j - - 1 b -	Yes   Yes  -	20.3 20.3 20.3 20.3 20.3 20.3 7.0	$a_{T}$ mass     960 GeV       N <sup>0</sup> mass     2.0 TeV       H <sup>±±</sup> mass     551 GeV       H <sup>±±</sup> mass     400 GeV       spin-1 invisible particle mass     657 GeV       multi-charged particle mass     785 GeV       monores     1.34 TeV       10 <sup>-1</sup> 1	1407.8150 1506.06020 1412.0237 1411.2921 1410.5404 1504.04188 Preliminary
						Mass scale [ lev	1

\*Only a selection of the available mass limits on new states or phenomena is shown.