Searches for vector-like quarks and ttbar resonances with the ATLAS detector

Jordan Webster on behalf of ATLAS

Joint with the TOP & Exotics groups

26 April 2013

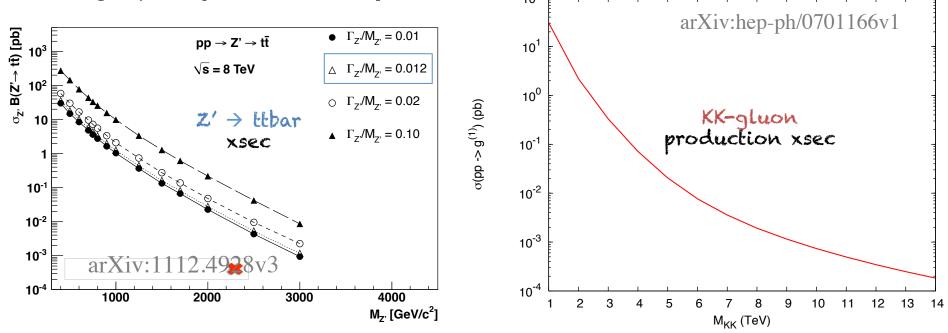
Key References: ATLAS-CONF-2012-136 ATLAS-CONF-2012-137 ATLAS-CONF-2013-018 arXiv:1211.2202



Motivation

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- Narrow Z' (EWSB)
 - Predicted by topcolor assisted technicolor [arXiv:hep-ph/9411426v2]
 - Can be leptophobic and decay to ttbar
- Kaluza-Klein gluon (Hierarchy problem)
 - Predicted by Randall-Sundrum warped extra dimension [arXiv:hep-ph/0701166v1]
 - Most strongly coupled of KK modes, decays primarily to ttbar
- Vector like quarks
 - Pair produced t' singlet/doublet, coupling to 3rd generation [arXiv:0907.3155v2]
 - Singly produced degenerate doublet, coupling to light quarks [arXiv:1102.1987]



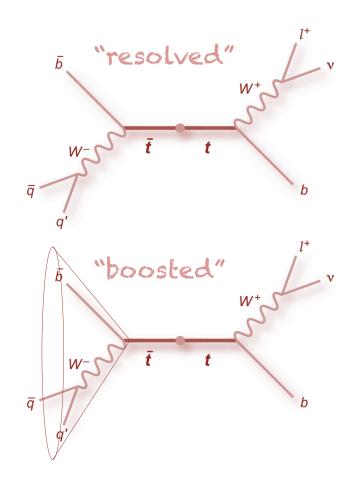
Final states to work with

$t\bar{t} \to \ell + E_T^{miss} + \text{jets}$

- Z', KK-gluons
- High pT jets
- Handle on multi-jet background
- $t\bar{t} \rightarrow jets$
 - Z', KK-gluons
 - Very high pT jets
 - Handle on leptonic backgrounds
 - Substructure
- $t'\bar{t}' \to HtHt, ZtHt, WbHt \ (H \to bb)$
 - Islated lepton + high jet multiplicity

 $Q + \text{jet} \rightarrow W + \text{jets}, Z + \text{jets}$

Isolated lepton(s) + at least 2 jets



Final states to work with

$t\bar{t} \rightarrow \ell + E_T^{miss} + \text{jets}$

- Z', KK-gluons
- High pT jets
- Handle on multi-jet background
- $t\bar{t} \rightarrow \text{jets}$
 - Z', KK-gluons
 - Very high pT jets
 - Handle on leptonic backgrounds

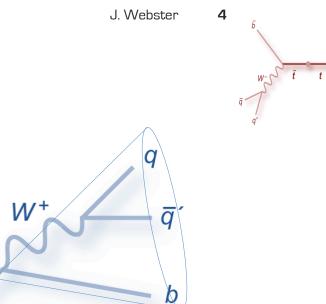
g

t

W-

- Substructure
- $t'\bar{t}' \rightarrow HtHt, ZtHt, WbHt \ (H \rightarrow bb$
 - Islated lepton + high jet multiplicity

 $Q + \text{jet} \rightarrow W + \text{jets}, Z + \text{jets}$ - Isolated lepton(s) + at least 2 jets



q

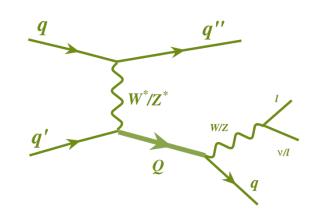
 \overline{q}

Final states to work with

 $t\bar{t} \rightarrow \ell + E_T^{miss} + \text{jets}$

- Z', KK-gluons
- High pT jets
- Handle on multi-jet background
- $t\bar{t} \rightarrow \text{jets}$
 - Z', KK-gluons
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 - Handle on leptonic backgrounds
 - Substructure
- $t'\bar{t}' \to HtHt, ZtHt, WbHt \ (H \to bb)$
 - Islated lepton + high jet multiplicity

 $Q + \text{jet} \rightarrow W + \text{jets}, Z + \text{jets}$ - Isolated lepton(s) + at least 2 jets



ť'

W

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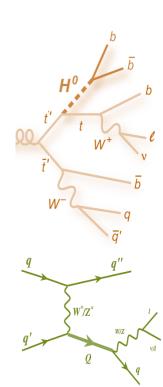
Analysis toolbox

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- Complicated final states \rightarrow lots of fun analysis techniques!
- b-tagging
- Fat jets
- Jet substructure
 - HEPTopTagger re-clustering
 - Top Template Tagger topology matching
- Data-driven background estimation
 - Matrix method for multi-jet background
 - W charge asymmetry method for W+jets background



ttbar \rightarrow lepton + jets

Data: 4.66 fb⁻¹, 7 TeV

 \bar{b} W^+ \bar{t} \bar{t} \bar{t} J. Webster 7

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Selection:

- Triggered either by single lepton or single fat jet trigger, $p_T > 240 \text{ GeV}$
- Exactly one isolated lepton with $p_T > 25$ GeV, $|\eta| < 2.5$ (2.47 for electrons)
- MET > 20 35 GeV depending on lepton flavor
- Require 1 boosted R=1.0 jet + a b-jet OR IF FAILS 4 resolved R=0.4 jets (3 if one has m_T > 60 GeV)

Model:

- ttbar MC@NLO, Herwig
- Single top MC@NLO, Herwig // AcerMC, Pythia
- W/Z+jets Alpgen, **W+jets normalization from data**
- Diboson Herwig, Jimmy
- Multijet events **data-driven** from matrix method
- Signal model from Monte Carlo (LO*k-factor) Z' (Pythia), KK-gluon (Madgraph)

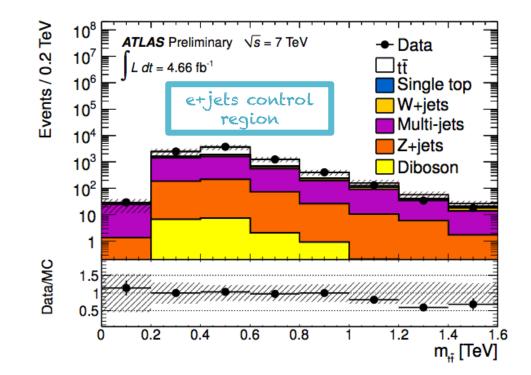
ttbar \rightarrow lepton + jets

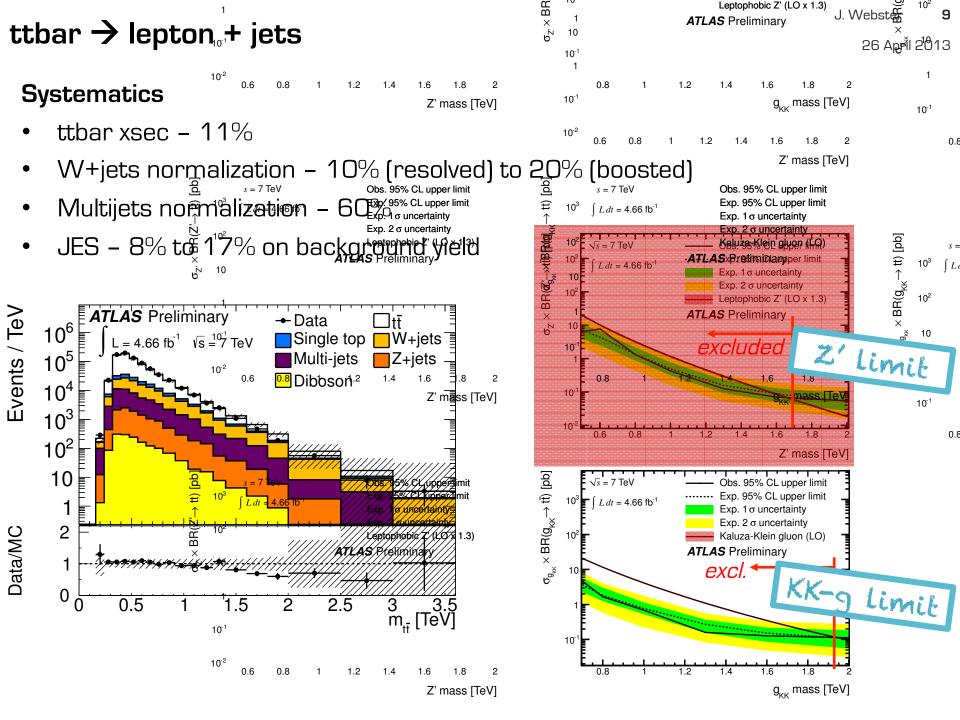
Event reconstruction

 In the case of 3 – 4 resolved jets, a chi-square algorithm is used to select the jet corresponding to semi-leptonically decaying top

$$\chi^{2} = \left[\frac{m_{jj} - m_{W}}{\sigma_{W}}\right]^{2} + \left[\frac{m_{jjb} - m_{jj} - m_{th-W}}{\sigma_{th-W}}\right]^{2} + \left[\frac{m_{j\ell\nu} - m_{t\ell}}{\sigma_{t\ell}}\right]^{2} + \left[\frac{(p_{\mathrm{T},jjb} - p_{\mathrm{T},j\ell\nu}) - (p_{\mathrm{T},th} - p_{\mathrm{T},t\ell})}{\sigma_{\mathrm{diff}p_{\mathrm{T}}}}\right]^{2}$$

- Correctly matches partons in 65% of ttbar events passing selection





ttbar \rightarrow jets

Selection:

- Events triggered by high E_T jets, or large jet multiplicity
- Want at least 2 fat jets tagged as tops
 - HEPTopTagger jet $p_T > 200 \text{ GeV}$
 - Top Template Tagger jet p_T > 450 GeV
- Each fat jet must have an associated b-tagged jet nearby

Model:

- ttbar MC@NLO, Herwig
- Multijet events data-driven from control region extrapolation
- Signal model from Monte Carlo (LO) Z' (Pythia), KK-gluon (Madgraph)

 W^+

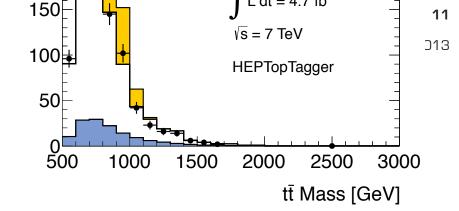
W

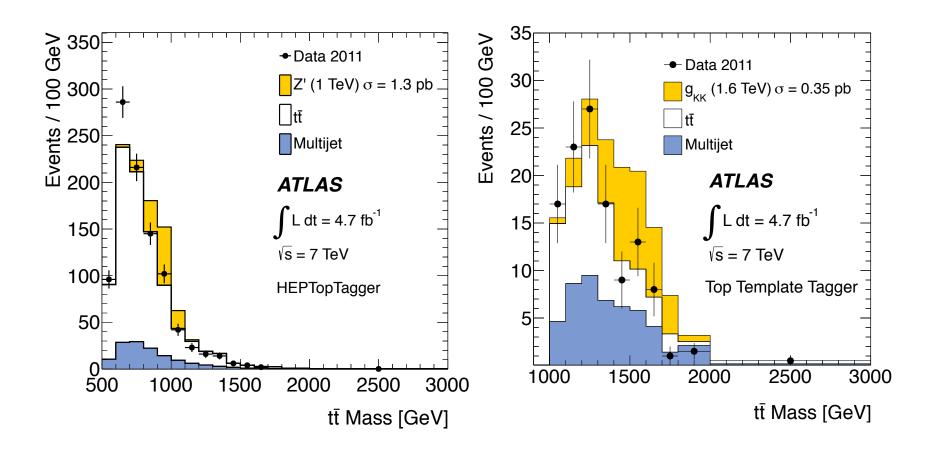
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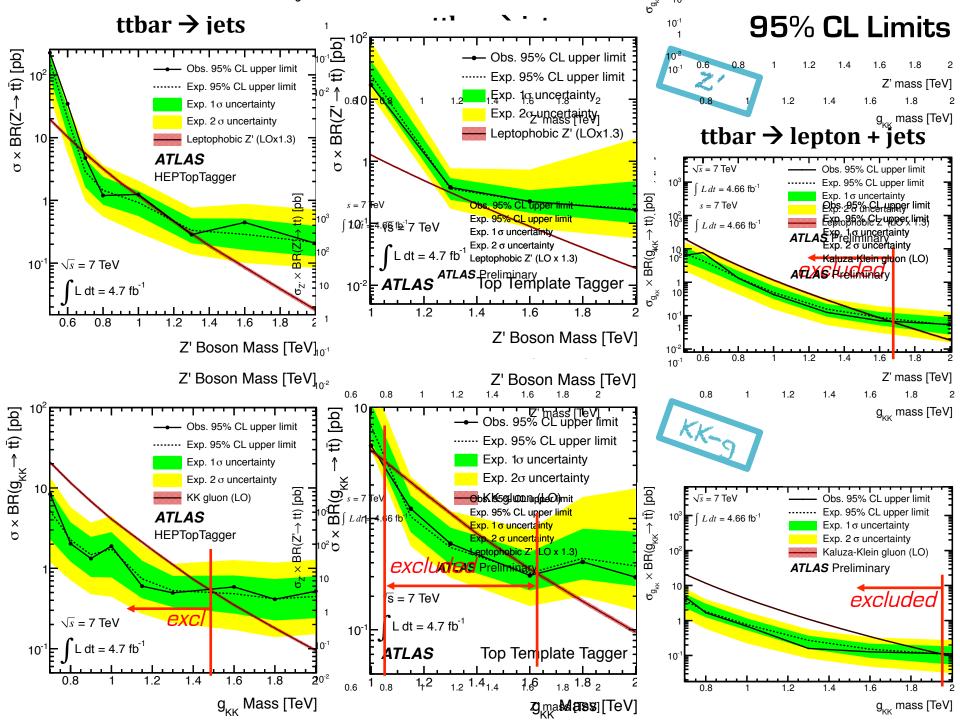
ttbar \rightarrow jets

Systematics

- Largest uncertainties from
 - b-tagging efficiency as large as 50% at
 - JES 2.3% to 6.8%







Pair produced VLQs

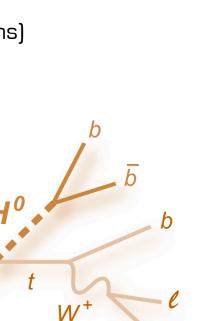
Data: 14.3 fb⁻¹, 8 TeV

Selection:

- Single lepton trigger
- Exactly 1 isolated lepton with $p_T > 25$ GeV, $|\eta| < 2.5$ (2.47 for electrons)
- MET > 20 GeV
- At least 6 jets with at least 2 b-tags

Model:

- ttbar + jets Alpgen, Herwig
- W/Z+jets Alpgen, **W+jets normalization from data**
- Multijet events **data-driven** using matrix method
- Single top MC@NLO, Herwig // AcerMC, Pythia
- ttV Madgraph, Pythia
- ttH (125 GeV) Pythia
- Diboson Herwig
- t' signal Protos

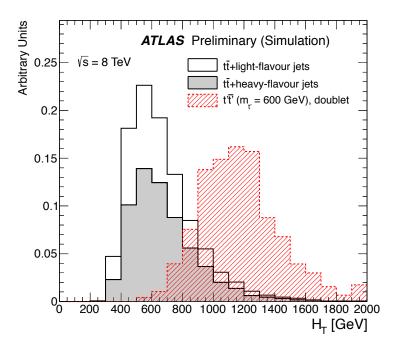


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Pair produced VLQs

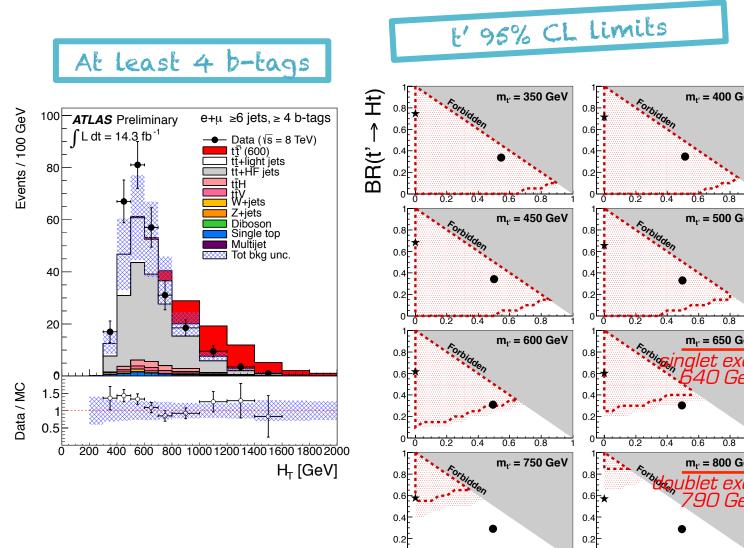
• Discrimination from H_T = scalar sum of all p_T in event



Systematics

- Uncertainty on **background** normalization largest for \geq 4 b-tags, 42%
 - Dominant uncertainties from ttbar modeling/xsec (32%), b-tag/c-tag efficiency (16%/11%), and JES (11%)
- Uncertainty on signal normalization largest for \geq 4 b-tags, 21%
 - Dominated by b-tag efficiency

Pair produced VLQs



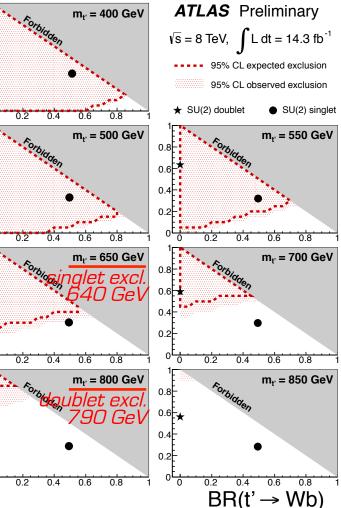
0

0

0.2

0.4

0.6



040

0.8

Singly produced VLQs

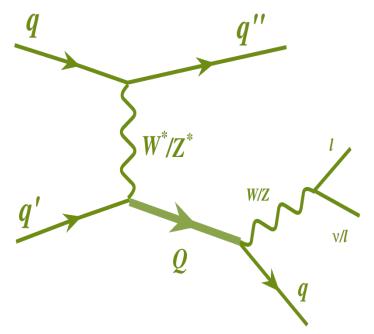
Data: 4.64 fb⁻¹, 7 TeV

Selection:

- Single or 2 lepton trigger depending on channel
- Select W or Z decaying to lepton(s)
- 2 or more jets, one with $p_T > 60 \text{ GeV}$

Model:

- Function fit to data
- MC used to determine fit function, optimize cuts
 - W/Z+jets Alpgen, Herwig
 - ttbar MC@NLO, Herwig
 - Diboson Herwig
- Signal generated seperately in W/Z channels in Madgraph



Singly produced VLQs

Modeling

• Final background estimation comes from a fit to data using form

$$f(m; p_{0,1,2,3}) = p_0 \cdot \frac{(1-x)^{p_1}}{x^{p_2 + p_3 \cdot \ln(x)}}$$

- Cross-checked on MC and in control regions
- A set of optimized rectangular cuts on uncorrelated variables
 - Acceptance ranges from 13 42%

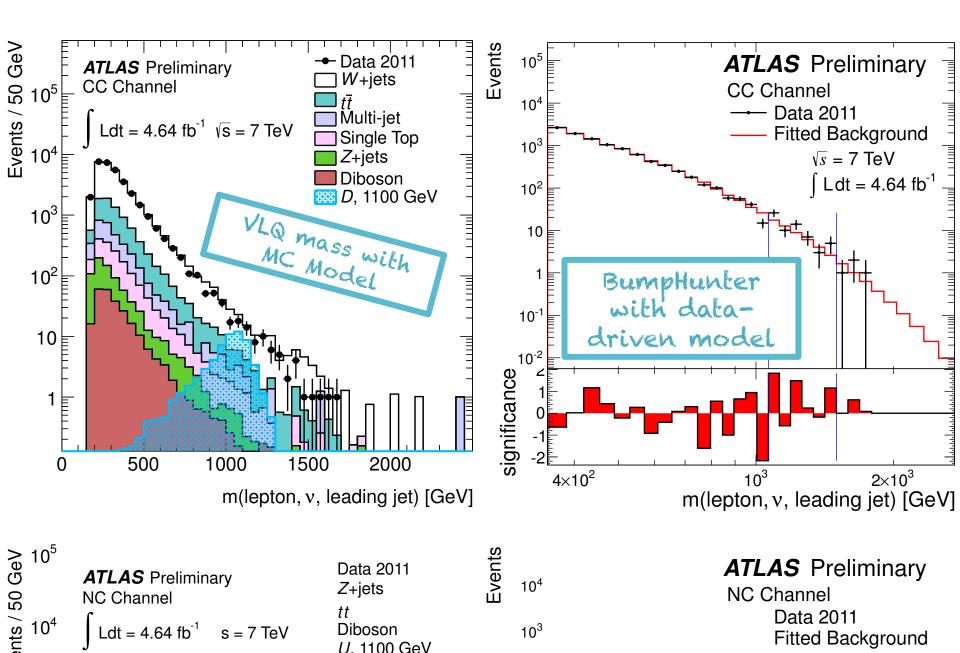
Systematics

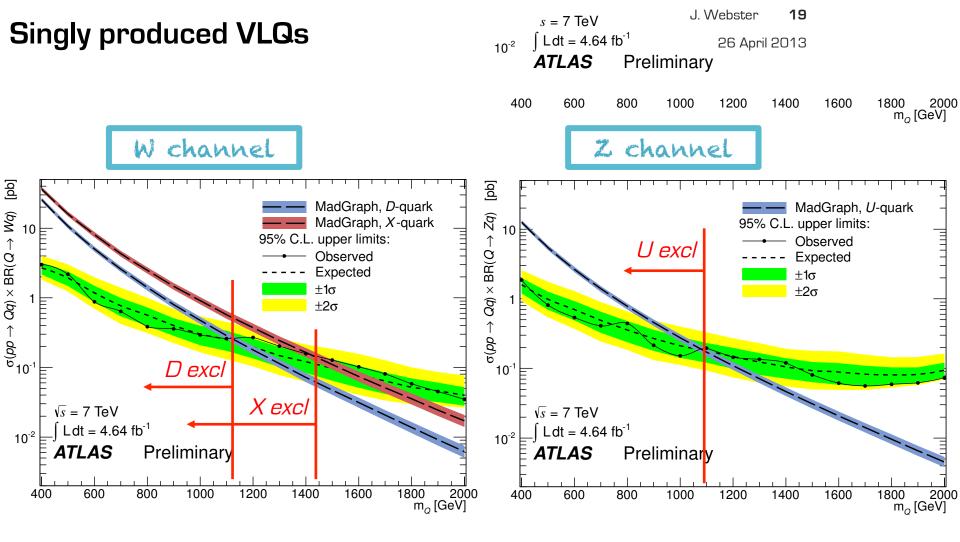
- Fit uncertainty varies from 5 15% across m_{VLQ} distribution
- Dominant signal normalization uncertainties from JES
 - 5 8% overall

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Singly produced VLQs – W channel





Qq) × BR($Q \rightarrow Zq$) [pb] 1 01

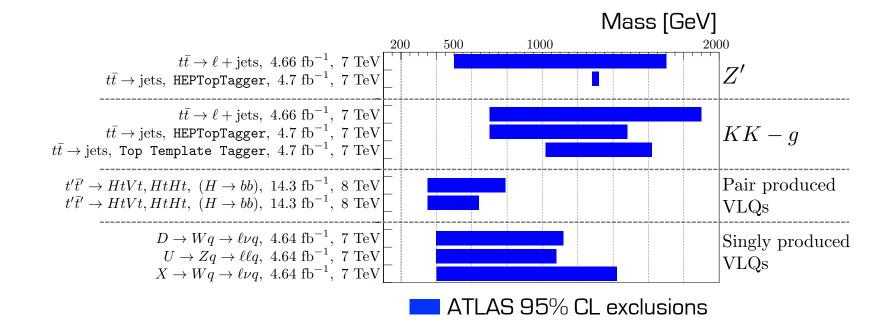
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MadGraph, *U*-quark 95% C.L. upper limits: Observed Expected ±1σ ±2σ

Conclusion

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- ATLAS results in these channels are so far consistent with SM
- Limits set on ttbar resonance models and VLQs



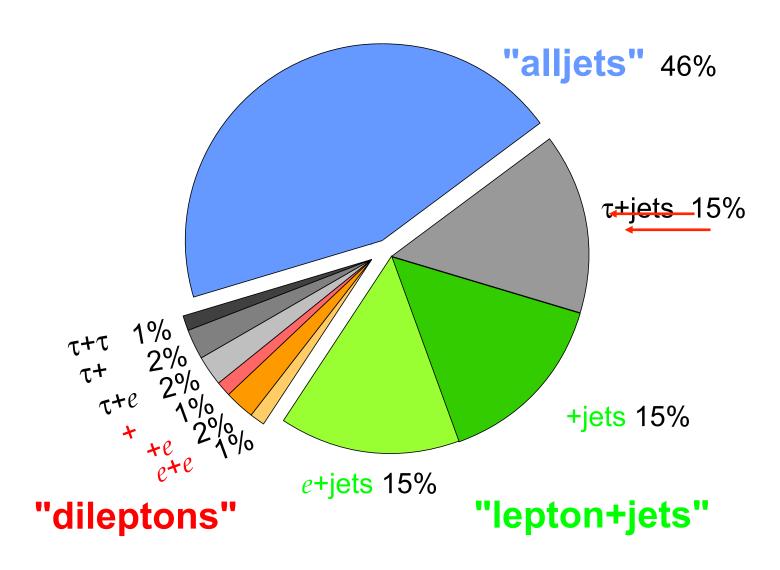
- MV tools for hadronic top tagging, b-tagging, jet substructure, are shown to be robust and expand the possibility for creativity in top channels
- Room for updates, higher energy data will offer a nice boost in sensitivity!

SECTION

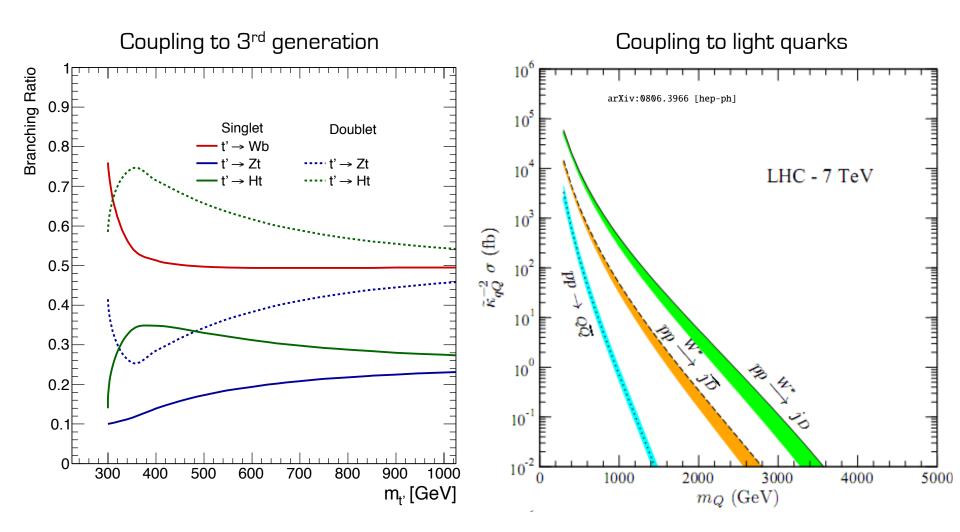
BACKUP

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Top Pair Branching Fractions

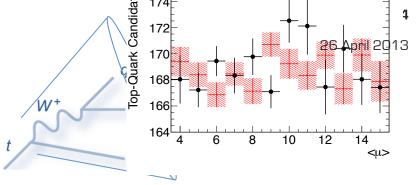


VLQ theory plots



ttbar \rightarrow jets

Reconstructing hadronically decaying tops



HEPTopTagger

- Driven by jet substructure and the C/A jet algorithm
- Use R = 1.5 jets, $p_T > 200$ GeV
- Maximum efficiency on signal:

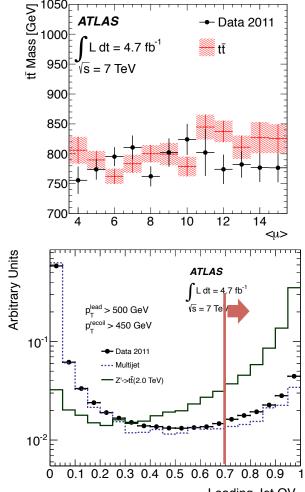
 $\varepsilon_{b\text{-tag, max}}^2 \cdot \varepsilon_{\text{top-tag, max}}^2 \approx 10\%$

Top Template Tagger

• Compare jet topology to library of 300K templates

$$OV_3 = \max_{\{\tau_n\}} \exp\left[-\sum_{i=1}^3 \frac{1}{2\sigma_i^2} \left(E_i - \sum_{\substack{\Delta R(\text{topo},i)\\ < 0.2}} E_{\text{topo}}\right)^2\right]$$

- Use R = 1.0 jets, $p_T > 450 \text{ GeV}$
- Efficiency for top quark selection near 75%



Leading Jet OV

ttbar \rightarrow jets – more multi-jet details

Data-driven components

- Control regions defined by loosening t/b-tag
 - Taking advantage of the fact that the t/b tags are uncorrelated
- For HEPTopTagger selection
 - Multi-jet shape averaged over control regions with 2 top-tags, normalization from region with 1 top-tag (< 2 b-tags)

→ 130 ± 70 (stat. \oplus syst.) multijet events in SR

- For Top Template Tagger selection
 - Multi-jet prediction from iterative technique, avoiding directly using data from regions with potential BSM contamination
 - → 53 +/-3 (stat) multijet events in SR

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ttbar \rightarrow jets : control regions

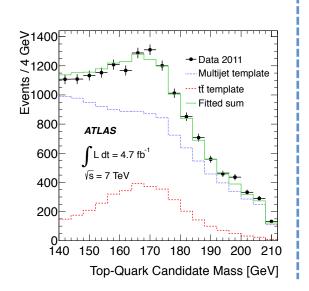
HEPTopTagger Analysis

	1 top-tag	≥ 2 top-tags
no <i>b</i> -tag	$\mathrm{U}(0.3\%)$	V(2.4%)
1 b-tag	W(3.2%)	X(24.3%)
$\geq 2 b$ -tags	Y(22.5%)	Z(80.9%)

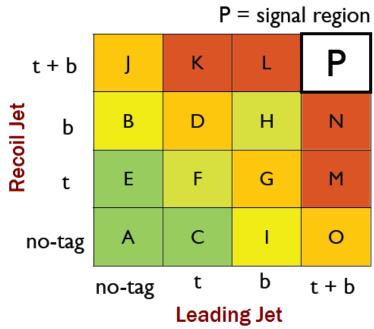
$$\text{multijet} \qquad \frac{\mathrm{d}n_Z}{\mathrm{d}m_{t\bar{t}}} = \left(\frac{1}{n_U} \times \frac{\mathrm{d}n_V}{\mathrm{d}m_{t\bar{t}}} + \frac{1}{n_W} \times \frac{\mathrm{d}n_X}{\mathrm{d}m_{t\bar{t}}}\right) \times \frac{n_Y}{2}$$

Ttbar normalization validation

Correction factor = 1.01 + - 0.09



Top Template Tagger Analysis



ttbar \rightarrow lepton + jets – Data-driven methods

Data-driven components

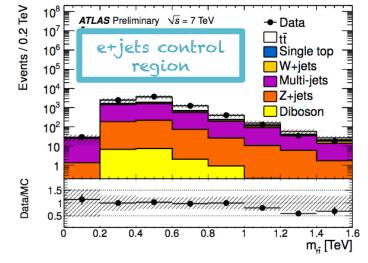
 W+jets normalization scaled to agree with data, using a ratio of estimated and predicted charge uncertainty

$$N_{W^+} + N_{W^-} = \left(\frac{r_{\rm MC} + 1}{r_{\rm MC} - 1}\right) (D_{\rm corr+} - D_{\rm corr-})$$

- Multijet normalization and shape from **matrix method**, cross-checked with jet-electron method
 - validated in low MET control region

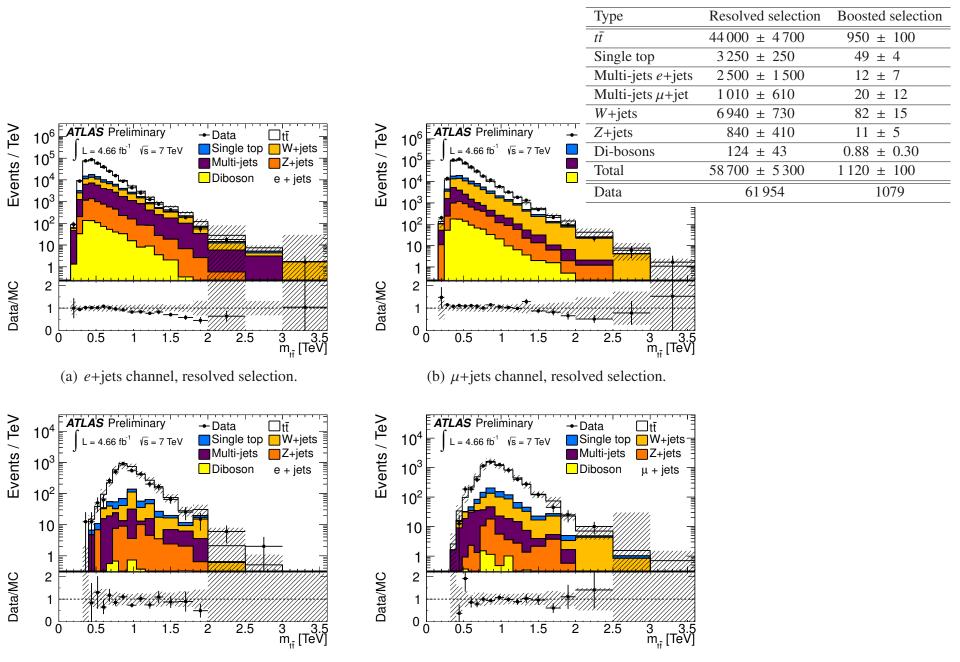
$$N^{\text{loose}} = N^{\text{loose}}_{\text{real}} + N^{\text{loose}}_{\text{fake}},$$

$$N^{\text{tight}} = \epsilon_{\text{real}} N^{\text{loose}}_{\text{real}} + \epsilon_{\text{fake}} N^{\text{loose}}_{\text{fake}},$$



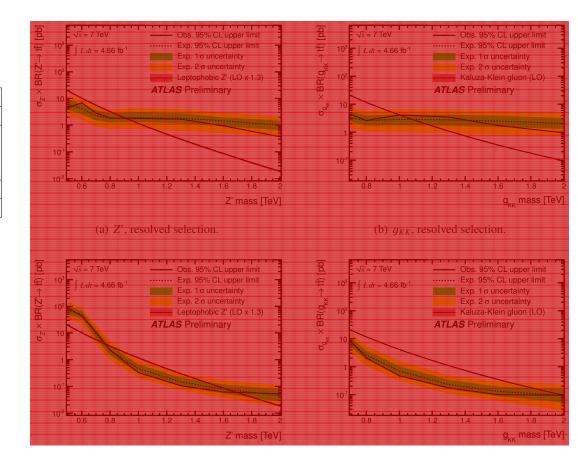
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ttbar \rightarrow lepton + jets results in separate channels



	Resolved selection		Boosted selection	
Impact on	yield [%]		yield [%]	
Systematic effect	total bgr.	Ζ'	total bgr.	Z'
ISR/FSR	0.3	_	5.9	_
PDF	3.5	_	7.9	_
$t\bar{t}$ normalization	8.0	_	9.0	_
EW Sudakov	1.9	_	4.2	_
$t\bar{t}$ higher order QCD corr.	1.2	_	9.0	_
W + heavy flavor	1.3	_	1.2	_
Multi-jets norm, <i>e</i> +jets	2.6	_	0.6	_
Multi-jets norm, μ +jets	1.0	_	1.1	_
Parton shower	0.2	_	7.3	_
JES, anti- $k_t R = 0.4$ jets	7.8	2.9	0.5	0.5
JES, anti- $k_t R = 1.0$ jets	0.2	4.8	17.0	2.8
<i>b</i> -tag efficiency	3.8	7.7	6.0	3.5
<i>c</i> -tag efficiency	1.2	0.6	0.1	2.5
Mistag rate	1.0	0.3	0.7	0.1

ttbar → lepton + jets limits in separate "resolved" and "boosted" searches





ttbar \rightarrow jets exclusions

Model	Obs. Limit (TeV)	Exp. Limit (TeV)			
HEPTopTagger					
Z'	$0.70 < m_{Z'} < 1.00$	$0.68 < m_{Z'} < 1.16$			
	$1.28 < m_{Z'} < 1.32$				
KK gluon	$0.70 < m_{g_{KK}} < 1.48$	$0.70 < m_{g_{KK}} < 1.52$			
Top Template Tagger					
KK gluon	$1.02 < m_{g_{KK}} < 1.62$	$1.08 < m_{g_{KK}} < 1.62$			

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Pair produced VLQ treatment of systematics

Systematic uncertainty	Туре	Components
Luminosity	Ν	1
Lepton ID+reco+trigger	Ν	1
Jet vertex fraction efficiency	S	1
Jet energy scale	SN	8
Jet energy resolution	SN	1
<i>b</i> -tagging efficiency	SN	9
<i>c</i> -tagging efficiency	SN	5
Light jet-tagging efficiency	SN	1
$t\bar{t}$ cross section	Ν	1
$t\bar{t}V$ cross section	Ν	1
<i>ttH</i> cross section	Ν	1
Single top cross section	Ν	1
Dibosons cross section	Ν	1
V+jets normalisation	Ν	1
Multijet normalisation	Ν	1
$t\bar{t}$ modelling	SN	3
$t\bar{t}$ +heavy-flavour fractions	Ν	1

Table 2: List of systematic uncertainties considered. A "N" means that the uncertainty is taken as normalisation-only for all processes and channels affected. A "SN" means that the uncertainty is taken as both shape and normalisation, although for small backgrounds only the normalisation uncertainty is considered. Some of the systematic uncertainties are split into several different components for a more accurate treatment.

Pair produced VLQ yields

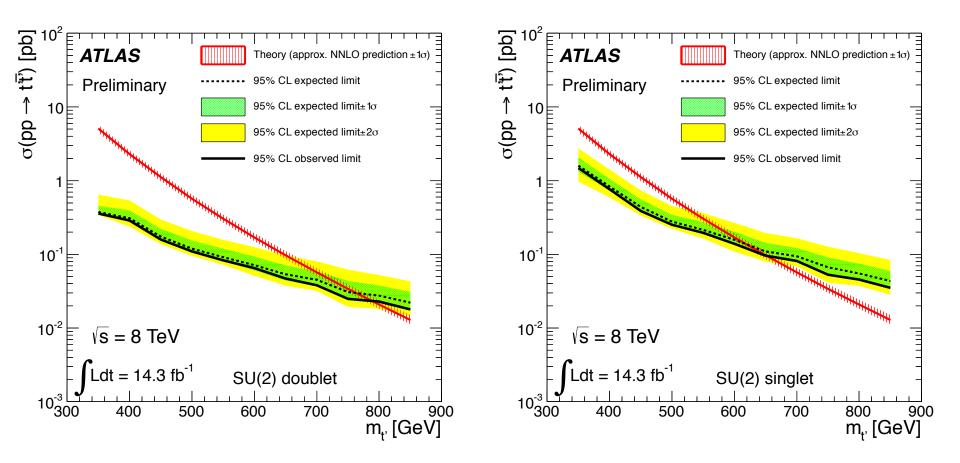
32

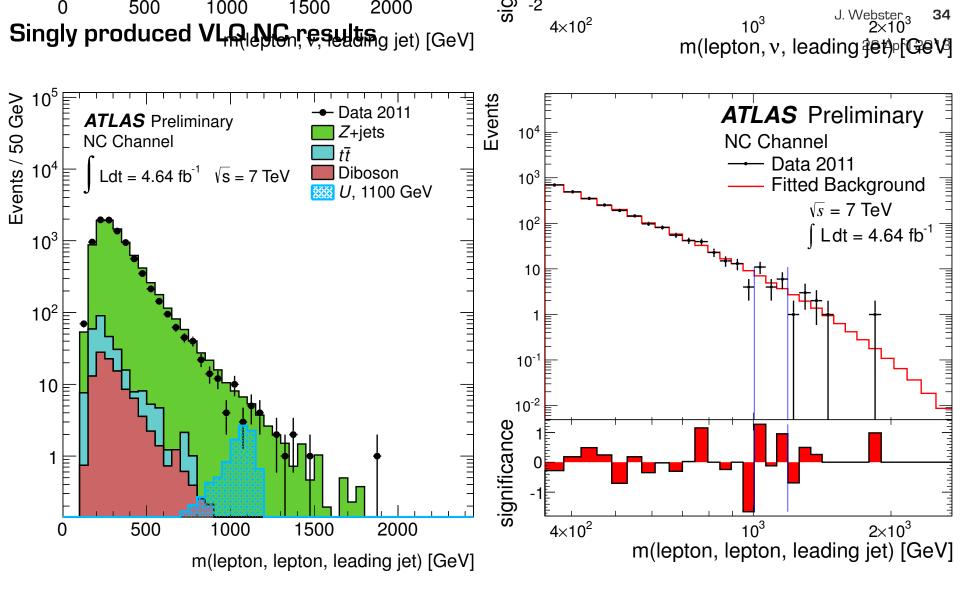
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\geq 6 jets, 2 <i>b</i> -tags	\geq 6 jets, 3 <i>b</i> -tags	\geq 6 jets, \geq 4 <i>b</i> -tags
1500 ± 900	900 ± 400	170 ± 70
9600 ± 1000	1900 ± 350	75 ± 22
250 ± 130	50 ± 30	5 ± 3
50 ± 40	9 ± 6	0.5 ± 0.9
300 ± 70	75 ± 18	7 ± 3
1.7 ± 0.6	0.3 ± 0.1	0.03 ± 0.03
70 ± 20	36 ± 12	7 ± 3
28 ± 4	31 ± 6	12 ± 3
49 ± 23	1.7 ± 0.8	0.15 ± 0.06
11860 ± 260	2990 ± 210	270 ± 60
11885	2922	318
550 ± 70	1100 ± 100	790 ± 160
4.3 ± 1.2	94 ± 7	79 ± 18
0.12 ± 0.05	10.7 ± 0.8	9.1 ± 2.1
290 ± 30	650 ± 80	330 ± 70
2.3 ± 0.4	61 ± 7	36 ± 9
0.06 ± 0.01	6.9 ± 0.7	4.2 ± 1.1
	1500 ± 900 9600 ± 1000 250 ± 130 50 ± 40 300 ± 70 1.7 ± 0.6 70 ± 20 28 ± 4 49 ± 23 11860 ± 260 11885 550 ± 70 4.3 ± 1.2 0.12 ± 0.05 290 ± 30 2.3 ± 0.4	1500 ± 900 900 ± 400 9600 ± 1000 1900 ± 350 250 ± 130 50 ± 30 50 ± 40 9 ± 6 300 ± 70 75 ± 18 1.7 ± 0.6 0.3 ± 0.1 70 ± 20 36 ± 12 28 ± 4 31 ± 6 49 ± 23 1.7 ± 0.8 11860 ± 260 2990 ± 210 11885 2922 550 ± 70 1100 ± 100 4.3 ± 1.2 94 ± 7 0.12 ± 0.05 10.7 ± 0.8 290 ± 30 650 ± 80 2.3 ± 0.4 61 ± 7

Pair produced VLQ model dependent limits

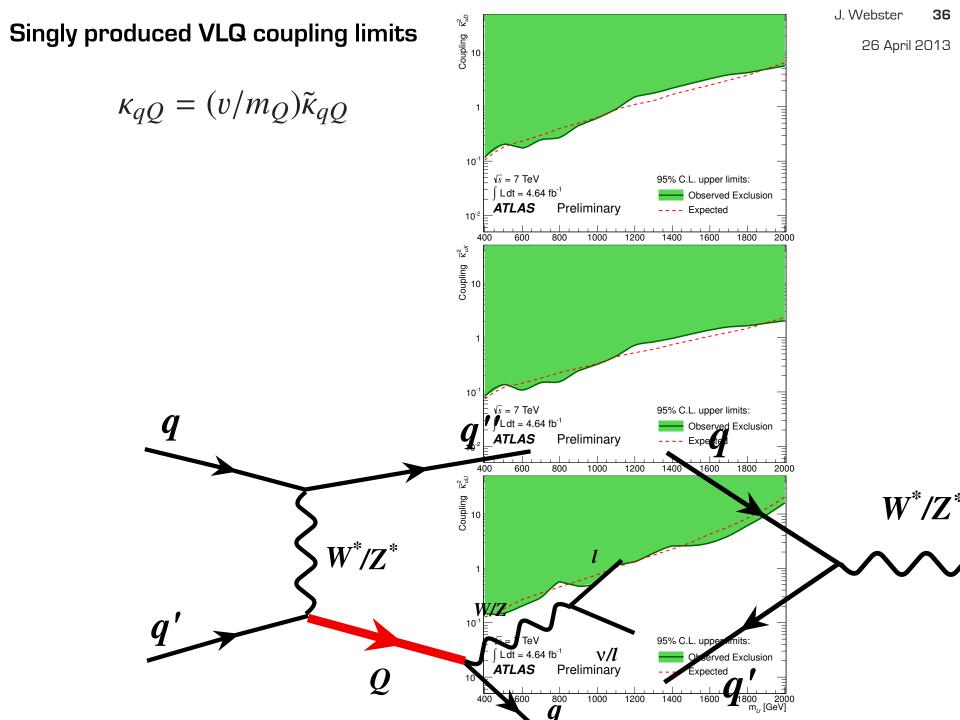




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Singly produced VLQ limits with negative lepton selection

 $\sigma(pp \to Qq) \times BR(Q \to Wq)$ [pb] After Negative Lepton Selection MadGraph, *D*-quark 95% C.L. upper limits: Observed Expected ±1σ ±2σ $\sqrt{s} = 7 \text{ TeV}$ $Ldt = 4.64 \text{ fb}^{-1}$ 10⁻² ATLAS Preliminary 00 2000 m_Q [GeV] 1200 400 600 800 1000 1400 1600 1800



Mass reach summary

ATLAS Exotics Searches* - 95% CL Lower Limits (Status: HCP 2012)

				```	
	Large ED (ADD) : monojet + $E_{T.miss}$	L=4.7 fb ⁻¹ , 7 TeV [1210.4491]		1.37 TeV M _D (δ=2)	
	Large ED (ADD) : monophoton + $E_{T,miss}$	L=4.6 fb ⁻¹ . 7 TeV [1209.4625]	1.93 TeV M _D		
SL	Large ED (ADD) : diphoton & dilepton, my /II	L=4.7 fb ⁻¹ , 7 TeV [1211.1150]		18 τεν <i>Μ_s</i> (HLZ δ=3, NL	O) ATLAS
Extra dimensions	UED : diphoton + $E_{T,miss}$	L=4.8 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-072]	1.41 TeV Compac		Preliminary
ISI	$S^{1}/Z_{2} ED$ : dilepton, $m_{\parallel}$	L=4.9-5.0 fb ⁻¹ , 7 TeV [1209.2535]		4.71 TeV M _{KK} ~ R ⁻¹	
e	RS1 : diphoton & dilepton, $m_{\gamma\gamma/II}$	L=4.7-5.0 fb ⁻¹ , 7 TeV [1210.8389]		Graviton mass $(k/M_{\rm Pl} = 0.1)$	1)
	RS1 : ZZ resonance, m	L=1.0 fb ⁻¹ , 7 TeV [1203.0718]	845 GeV Graviton mass		<b>^</b>
2	RS1 : WW resonance, m _{T.blv}	L=4.7 fb ⁻¹ , 7 TeV [1208.2880]	1.23 TeV Graviton r	mass $(k/M_{\rm pl} = 0.1)$	$Ldt = (1.0 - 13.0) \text{ fb}^{-1}$
110	$DC \alpha \rightarrow H (DD - 0.025) + H \rightarrow Luioto m$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-136]	<b>1.9 Те</b> V Д _{КК}	mass	
Ś	ADD BH ( $M_{\text{TH}}/M_{\text{D}}$ =3) : SS dimuon, $N_{\text{ch. part.}}$	L=1.3 fb ⁻¹ , 7 TeV [1111.0080]	1.25 TeV <i>M</i> _D (δ=6)		s = 7, 8 TeV
-	ADD BH $(M_{TH}/M_{D}=3)$ : leptons + jets, $\Sigma p_{T}$	L=1.0 fb ⁻¹ , 7 TeV [1204.4646]	$1.5 \text{ TeV}  M_D (\delta =$	:6)	
	Quantum black hole : dijet, F $(m_{ij})$	L=4.7 fb ⁻¹ , 7 TeV [1210.1718]		11 TeV Μ _D (δ=6)	
	gggg contact interaction : $\chi(m)$	L=4.8 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-038]		7.8 TeV Λ	
5	qqll Cl : ee & μμ, <i>m</i>	L=4.9-5.0 fb ⁻¹ , 7 TeV [1211.1150]			$\Lambda$ (constructive int.)
)	uutt CI : SS dilepton + jets + $E_{T,miss}$	$L=1.0 \text{ fb}^{-1}$ , 7 TeV [1202.5520]	1.7 TeV $\Lambda$	13.9 164	
	$Z'(SSM): m_{ee/\mu\mu}$	L=5.9-6.1 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-12		7' mass	
	$Z'(SSM): m_{ee/\mu\mu}$ $Z'(SSM): m_{\tau\tau}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1210.6604]	1.4 TeV Z' mass		
	$W'$ (SSM) : $m_{T,e/u}$	$L=4.7 \text{ fb}^{-1}$ , 7 TeV [1209.4446]		W' mass	
>	W' ( $\rightarrow$ tq, g _p =1) : $m_{tq}$			W IIId55	
	$W_{B}^{\prime}$ ( $\rightarrow$ tb, SSM) : $m_{L}$	L=4.7 fb ⁻¹ , 7 TeV [1209.6593] L=1.0 fb ⁻¹ , 7 TeV [1205.1016]	430 GeV W' mass		
	$W_{\rm R}$ ( $\sim$ 10, 00 M) $\cdot$ 11 to		1.13 TeV W' mass	\//* maaa	
	$W^*: m_{T,e/\mu}$	L=4.7 fb ⁻¹ , 7 TeV [1209.4446]		vv mass	
3	Scalar LQ pair ( $\beta$ =1) : kin. vars. in eejj, evjj	L=1.0 fb ⁻¹ , 7 TeV [1112.4828]	660 GeV 1 st gen. LQ mass		
Ĺ.	Scalar LQ pair ( $\beta$ =1) : kin. vars. in $\mu\mu jj$ , $\mu\nu jj$	L=1.0 fb ⁻¹ , 7 TeV [1203.3172]	685 GeV 2 nd gen. LQ mass		
	Scalar LQ pair (β=1) : kin. vars. in ττjj, τvjj	L=4.7 fb ⁻¹ , 7 TeV [Preliminary]	538 GeV 3rd gen. LQ mass		
2	$4^{\text{th}}$ generation : t't' $\rightarrow$ WbWb	L=4.7 fb ⁻¹ , 7 TeV [1210.5468]	656 GeV t' mass		
Excli. New quarks ferm.	4 th generation : b'b'( $T_{5/3}$ ) $\rightarrow$ WtWt New quark b' : b'b' $\rightarrow$ Zb+X, $m_{7b}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-130]	670 GeV b' (T _{5/3} ) mass		
h h	Top portport TT $_{2}$ tt $_{2}$ $\Lambda$ (dilaptop M ^{Zb} )		400 GeV b' mass	10	
A	Top partner : $TT \rightarrow tt + A_0 A_0$ (dilepton, $M_{T^2}^{20}$ )	L=4.7 fb ⁻¹ , 7 TeV [1209.4186]	<b>483 GeV</b> T mass $(m(A_{0}) < 100 \text{ G})$		
2	Vector-like quark : CC, m ² _{lvq}	L=4.6 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-137]		(charge -1/3, coupling $\kappa_{q0}$	
	Vector-like quark : NC, m _{ilq}	L=4.6 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-137]		charge 2/3, coupling $\kappa_{qQ}$	$= v/m_{Q}$ )
Ξ.E	Excited quarks : y-jet resonance, m	L=2.1 fb ⁻¹ , 7 TeV [1112.3580]	2.46 TeV		
ferm.	Excited quarks : dijet resonance, $\ddot{m}_{jj}$	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-148]		4 TeV q* mass	
	Excited lepton : I- $\gamma$ resonance, $m_{\gamma}$	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-146]		mass $(\Lambda = m(l^*))$	
Toohni	Techni-hadrons (LSTC) : dilepton,m _{ee/µµ}	L=4.9-5.0 fb ⁻¹ , 7 TeV [1209.2535]	<mark>850 GeV</mark> ρ _τ /ω _τ mass ( <i>m</i> (		
recrim-	hadrons (LSTC) : WZ resonance (vIII), $m_{T,WZ}$	L=1.0 fb ⁻¹ , 7 TeV [1204.1648]	<b>483 GeV</b> $\rho_{\rm T}$ mass $(m(\rho_{\rm T}) = m(\pi_{\rm T})$		
อ เ	Major. neutr. (LRSM, no mixing) : 2-lep + jets	L=2.1 fb ⁻¹ , 7 TeV [1203.5420]		s ( <i>m</i> (W _R ) = 2 TeV)	_
	$W_R$ (LRSM, no mixing) : 2-lep + jets	L=2.1 fb ⁻¹ , 7 TeV [1203.5420]		$W_R$ mass ( $m(N) < 1.4$ TeV	')
) F	$I_{\perp}^{\pm\pm}$ (DY prod., BR( $I_{\perp}^{\pm\pm} \rightarrow II$ )=1) : SS ee ( $\mu\mu$ ), m		409 Gev HL ^{±±} mass (limit at 398 Ge)	V for μμ)	
	$H_{L}^{\pm\pm}$ (DY prod., BR( $H_{e\mu}^{\pm\pm} \rightarrow e\mu$ )=1) : SS $e\mu$ , $m_{e\mu}^{\parallel}$		75 GeV H ^{±±} mass		
	Color octet scalar : dijet resonance, $\breve{m}_{jj}$	L=4.8 fb ⁻¹ , 7 TeV [1210.1718]	1.86 TeV Sca	lar resonance mass	
		10 ⁻¹	1	10	1
					Mass scale [TeV]
*Only a sele	ction of the available mass limits on new states o	r phenomena shown			IVIASS SCALE [TEV]

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