

# Searches for new physics in high-mass di-fermion final states with the ATLAS detector at the LHC

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# Signature dependent searches

# High mass $ee$ and $\mu\mu$ resonances

ATLAS  
high-mass  
di-fermion  
final states

J. Veatch

Dilepton

Dijet

$\tau^+ \tau^-$

$t\bar{t}$

$W'/W^*$

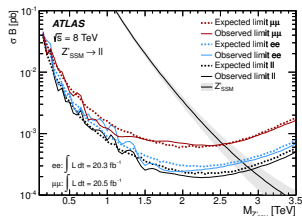
Heavy  $\ell$

LFV

Summary

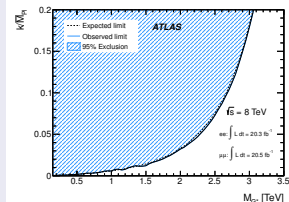
Backup  
Slides

- Many models decay to opposite-sign  $ee$  or  $\mu\mu$
- Require exactly 2 leptons with  $m_{\ell\ell} > 128$  GeV
- Interference from  $Z/\gamma^*$  included in analysis
- [arXiv:1405.4123](https://arxiv.org/abs/1405.4123)



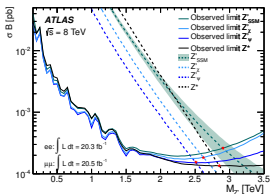
## Randall-Sundrum graviton

- Spin-2  $G^*$  characterized by mass and  $k/\overline{M}_{Pl}$
- Set limits for  $k/\overline{M}_{Pl} < 0.2$

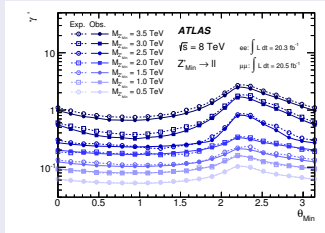
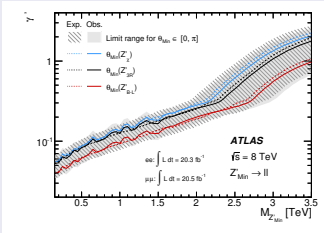


# High mass $ee$ and $\mu\mu$ resonances cont'd

## $Z'$ models

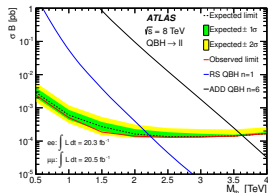


- $Z'_{SSM}$  used as a benchmark
- $E_6$  group narrow  $Z'_\psi$  and  $Z'_\chi$
- Minimal  $Z'$  characterized by  $m_{Z'}$ ,  $\theta_{Min}$ , and  $\gamma'$
- Vector boson doublet,  $Z'^*$



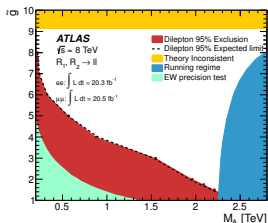
## Quantum black holes

- RS and ADD models studied
- Assume conserved color, charge, and  $\vec{L}$
- Limits set on  $M_{\text{th}}$



## Minimal walking technicolor

- Technimeson resonances test MWT model
- Limits set on  $M_A$  and  $\tilde{g}$



# Dijet resonances

ATLAS  
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di-fermion  
final states

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Dilepton

Dijet

$\tau^+ \tau^-$

$t \bar{t}$

$W^+ / W^-$

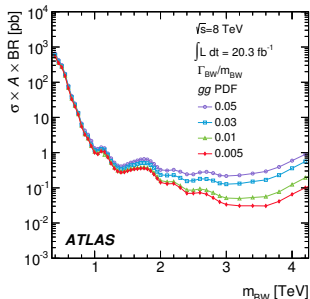
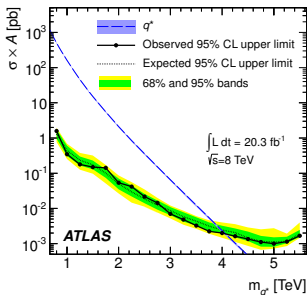
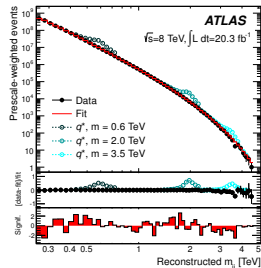
Heavy  $\ell$

LFV

Summary

Backup  
Slides

- Search for resonances in  $m_{jj}$  spectrum
- Benchmark models:  $q^*$ ,  $s_8$ ,  $W^*$ , and QBH
- Generalized resonances also studied
- Using events with 2 high  $p_T$  jets
- [arXiv:1407.1376](https://arxiv.org/abs/1407.1376)



# Quark compositeness

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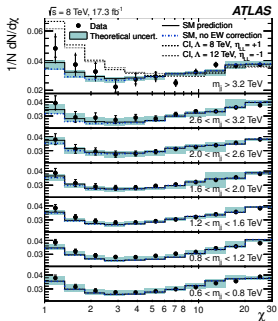
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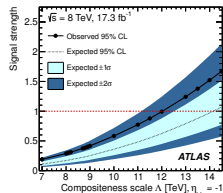
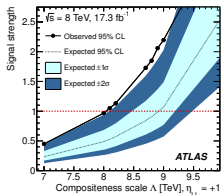
Summary

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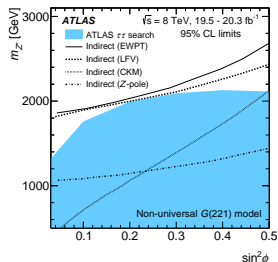
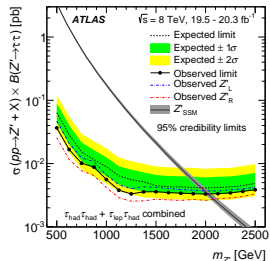
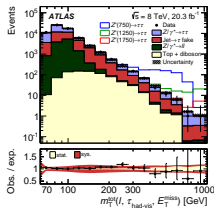
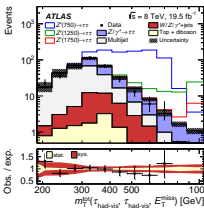


- Constructive and destructive interference quark compositeness
- Search using dijet event kinematics
- Discriminant is angular variable  $\chi = e^{|y_1 - y_2|}$
- Limits set on characteristic energy scale,  $\Lambda$
- [arXiv:1504.00357](https://arxiv.org/abs/1504.00357)



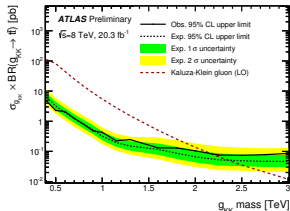
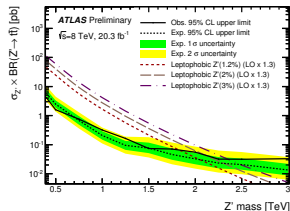
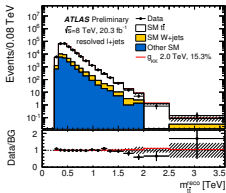
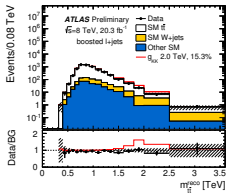
# High-mass $\tau^+\tau^-$ resonances

- Di-tau searches are sensitive to new physics
  - Non-universal and hidden sector  $Z'$
  - Goldstino-like scalars
  - Anomalous  $\tau$  dipole moments
- Benchmark models are  $Z'_{SSM}$  and G(221) (indirect)
  - $Z'_L$  and  $Z'_R$  are also used
- $\tau_{had}\tau_{had}$  and  $\tau_{lep}\tau_{had}$  channels considered
- $m_T(\tau_1, \tau_2, E_T^{miss})$  is the primary discriminant
- [arXiv:1502.07177](https://arxiv.org/abs/1502.07177)





- Single lepton+jets “golden” channel
  - Good BR and background rejection
- Benchmark models: leptophobic  $Z'$ ,  $g_{KK}$ ,  $G_{KK}$ , spin-0 scalar
- Using both resolved and boosted topologies
- Limits set on reconstructed  $m_{t\bar{t}}$
- [ATLAS-CONF-2015-009](#)



# Model dependent searches

# $W' \rightarrow tb$

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$t \bar{t}$

$W' / W^*$

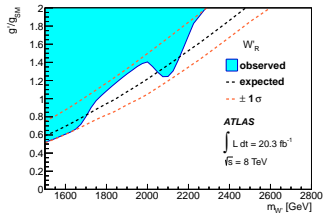
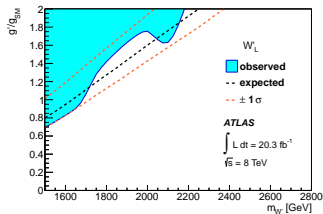
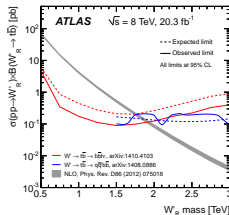
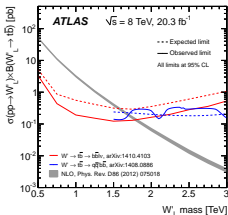
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LFV

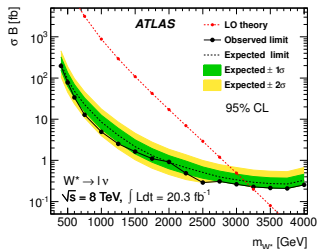
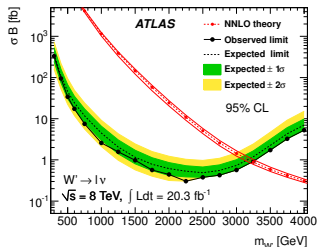
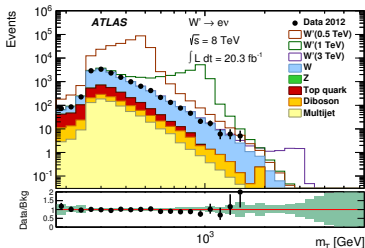
Summary

Backup  
Slides

- Numerous theories predict  $W'_L$  and  $W'_R$
- Search for an effective  $W'$  model
  - Parameterized only by  $m_{W'}$  and  $g'/g_{SM}$
- $W' \rightarrow tb \rightarrow qqbb$  or  $W' \rightarrow tb \rightarrow \ell\nu bb$
- Leptonic selection: identification with BDT
- Hadronic selection: jet substructure to tag top
- Limits set on  $m_{tb}$  and  $g'/g_{SM}$
- [arXiv:1410.4103](https://arxiv.org/abs/1410.4103) and [arXiv:1408.0886](https://arxiv.org/abs/1408.0886)



- Search for  $W'$  and  $W^*$  in  $l\nu$  channel
  - Performed in parallel to  $\chi\bar{\chi} + l$  search
- Transverse mass is the discriminating variable
- [arXiv:1407.7494](https://arxiv.org/abs/1407.7494)



# Heavy leptons

ATLAS  
high-mass  
di-fermion  
final states

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Dilepton

Dijet  
 $\tau^+ \tau^-$

$t\bar{t}$   
 $W' / W^*$

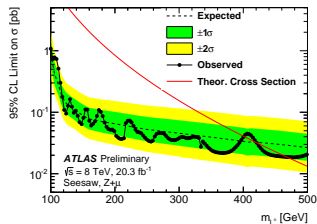
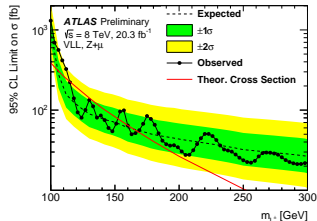
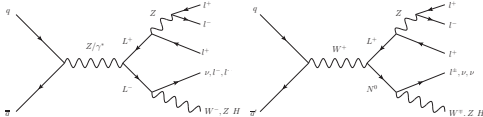
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LFV

Summary

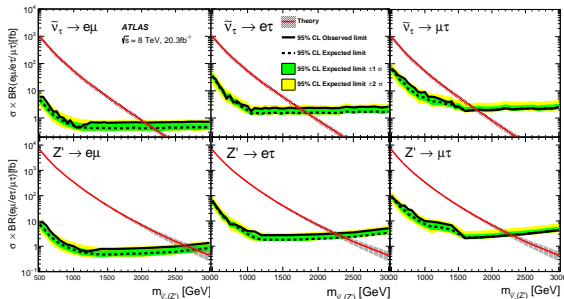
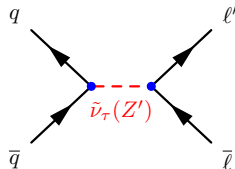
Backup  
Slides

- Vector-like leptons and type-III seesaw leptons
- Couple to SM leptons and gauge bosons
- Consider  $L^\pm L^\mp$  and  $L^\pm N^0$  (seesaw) production
- $\geq 4\ell$ ,  $3\ell+jj$ , and  $\geq 3\ell$  channels



# Lepton flavor violating heavy neutral particles

- RPV SUSY allows  $\tilde{\nu}_\tau \rightarrow \ell\ell'$ 
  - Produced by  $d\bar{d}$  annihilation
- SSM can be extended to include  $Z'$  LFV couplings
- Opposite sign  $e\mu$ ,  $e\tau_{had}$ , and  $\mu\tau_{had}$  signatures
- Boosted decision tree used to identify  $\tau_{had}$
- $m_{\ell\ell'}$  is the final observable
- [arXiv:1503.04430](https://arxiv.org/abs/1503.04430)



- Many different BSM searches using di-fermion final states
  - Di-lepton
  - Di-jet
  - Di-top
  - $\ell\nu$
  - LFV di-lepton
  - Heavy leptons
- No significant excesses observed
- Limits set on mass and other model parameters
- Run 2 will bring more interesting results

# Backup Slides



# Dijet resonances

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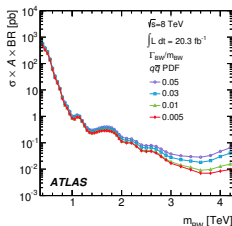
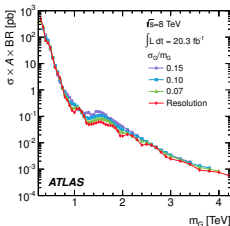
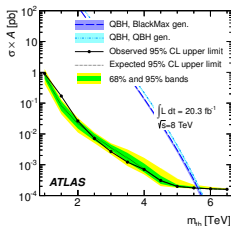
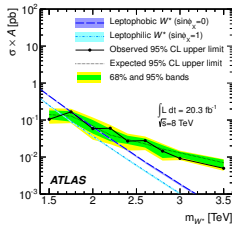
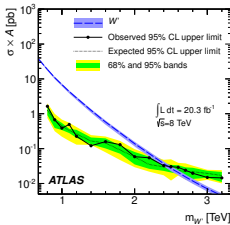
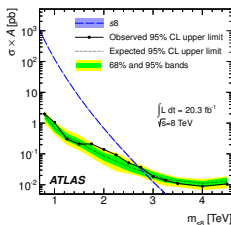
$W' / W^*$

Heavy  $\ell$

LFV

Summary

Backup  
Slides



# High-mass $\tau^+\tau^-$ resonances: selection

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Dilepton

Dijet

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$t\bar{t}$

$W'/W^*$

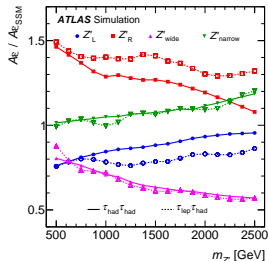
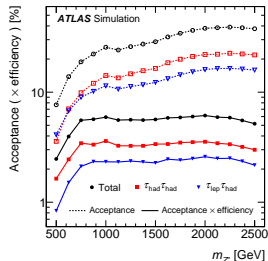
Heavy  $\ell$

LFV

Summary

Backup  
Slides

- $\tau_{had}\tau_{had}$ 
  - $=0$   $e$  and  $\mu$
  - $\geq 2$   $\tau$  candidates
    - Reconstructed with anti- $k_t$  algorithm
    - Leading  $p_T > 150$  GeV
    - Subleading  $p_T > 50$  GeV
  - $\Delta\phi(\tau_1, \tau_2) > 2.7$
- $\tau_{lep}\tau_{had}$ 
  - $=1$   $e$  or  $\mu$
  - $\geq 1$   $\tau$  candidate with  $p_T > 30$  GeV
  - $\Delta\phi(\ell, \tau) > 2.7$
- Primary backgrounds
  - $Z/\gamma^* \rightarrow \tau\tau$
  - Multijet processes
    - jet  $\rightarrow$  fake  $\ell$  for  $\tau_{lep}\tau_{had}$



# $t\bar{t}$ resonances: selection and reconstruction

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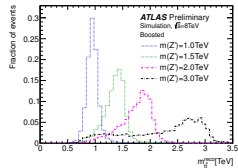
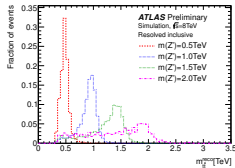
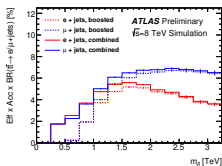
Heavy  $\ell$

LFV

Summary

Backup  
Slides

- Require exactly 1 lepton ( $e$  or  $\mu$ )
- High  $E_{T,miss}$  and  $m_{T,W}$
- Reconstruct  $\nu$  from  $E_{T,miss}$  and  $m_W$  constraint
- Boosted topology
  - Large- $R$  jet with  $m > 100$  GeV and  $\sqrt{d_{12}} > 40$  GeV for hadronic top
  - Leptonic top uses leading small- $R$  jet near lepton
- Resolved topology
  - Only for events that fail boosted selection
  - $\geq 4$  small- $R$  jets
  - Reconstructed using  $\chi^2$  method



# $t\bar{t}$ resonances: limits

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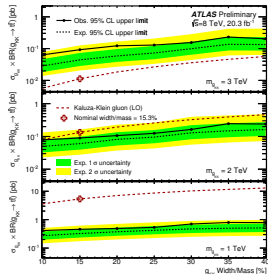
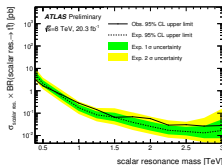
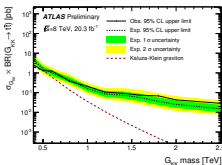
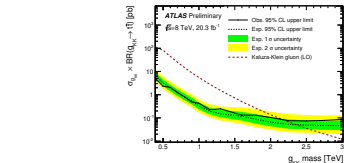
$W'/W^*$

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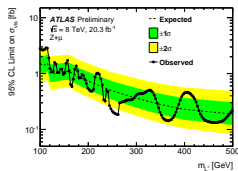
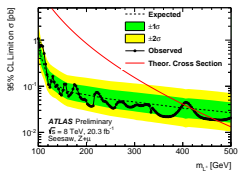
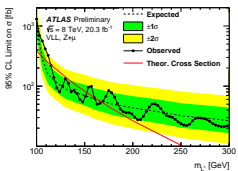
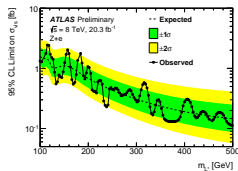
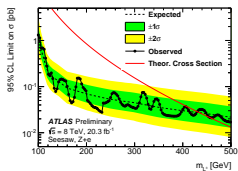
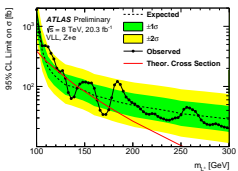
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# Lepton flavor violating heavy neutral particles: selection

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Summary

Backup  
Slides

- Require exactly 2 opposite sign leptons with different flavors
  - $|\Delta\phi_{\ell\ell'}| > 2.7$
  - Energy is lost to  $\nu$  from  $\tau$  decay:  $E_T^\tau < p_T^{\nu,\mu}$
- Prompt lepton SM backgrounds from MC
- Fake lepton backgrounds ( $W$ +jets and multijet) from data driven estimate

