Exotics Searches at ATLAS

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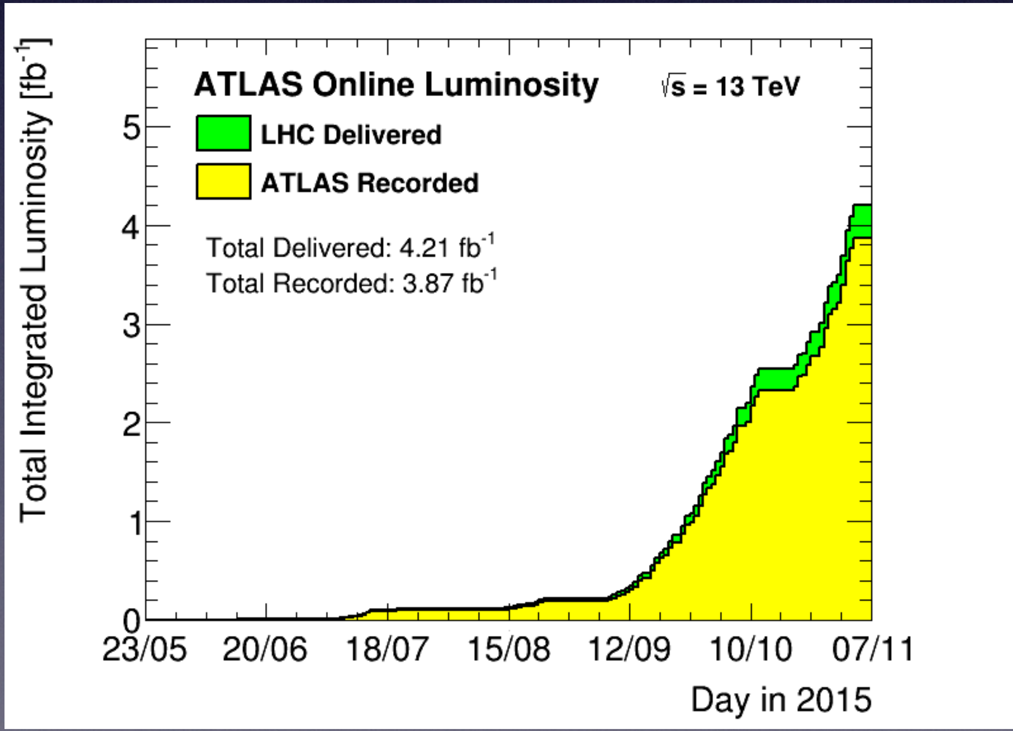
Exotics at the LHC

- "Exotics" means direct searches for particles/phenomena:
  - beyond the Standard Model
  - not supersymmetry or BSM Higgs (see talks from P. Klimek, D. Xu, and M. Schioppa)
- Leaves a huge range of hypotheses that explain one or more of the mysteries in the SM
- These searches benefit greatly from the increased LHC energy
  - with ~3 fb^{-1} at 13 TeV, we have already exceeded Run 1 sensitivity in many cases



Outline

- Will focus on results using the 2015 data sample
- Many final states represented:
  - dibosons ($\ell\nu qq$, $\ell\ell qq$, $[\nu\nu/\ell\nu/\ell\ell]bb$, $\nu\nu qq$ and all-hadronic final states)
  - dijets
  - multijets
  - 1 lepton plus missing E_{T}
  - same-flavor dilepton
  - $e\mu$

Searches for Diboson Production

- Diboson final states (*WW*, *WZ*, *ZZ*) can be used to search for a variety of heavy resonances
  - mass constraints on the final state bosons enhance S/B ratio
- Models considered:
  - heavy SM-like Higgs boson (spin 0, CP odd) with various widths
  - Randall-Sundrum graviton
  - Generic “Heavy Vector Triplet” formulation

    D. Pappadopulo et al., JHEP09 (2014) 060
    - limits can be translated to a wide variety of models
- Search in a variety of modes, depending on whether bosons decay hadronically or leptonically

Hadronic Boson Tagging

- Any new resonance decaying to *VV* must be heavy
  - hadronic *W/Z* products likely to overlap in calorimeter
- Boosted jet tagging methods used in all diboson searches:
- Jets reconstructed with $R = 1.0$
- "Trimmed" by removing low-p_T $R = 0.2$ subjets
- Requirement placed on ratio of subjet energy correlations
- Jet mass required to be within 15 Gev of *W* or *Z* mass

arXiv: 1510.05821 [hep-ex]

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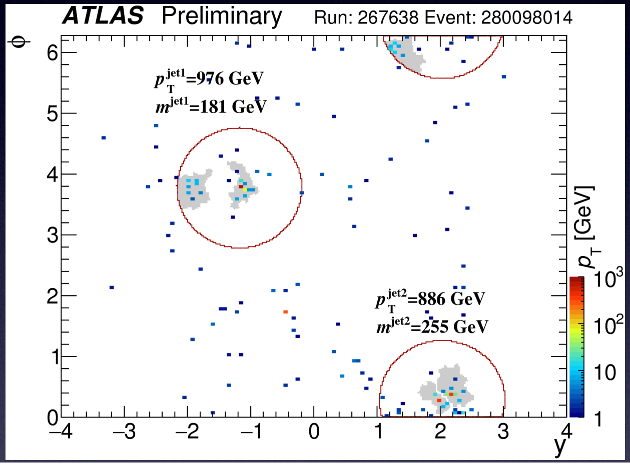
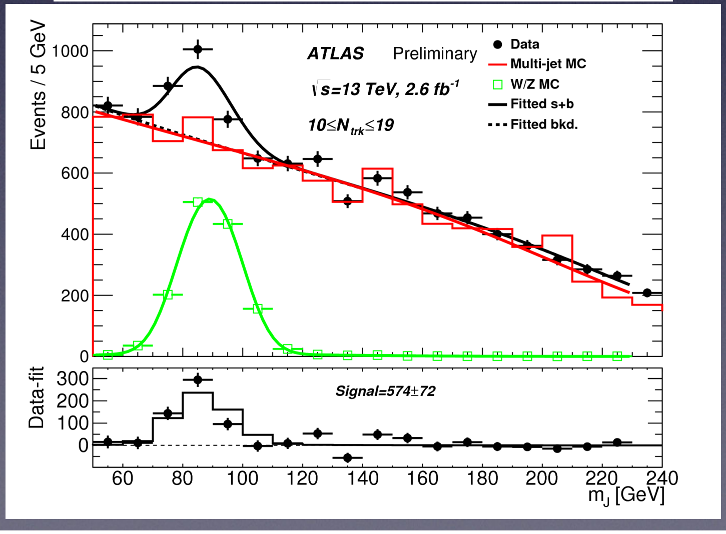
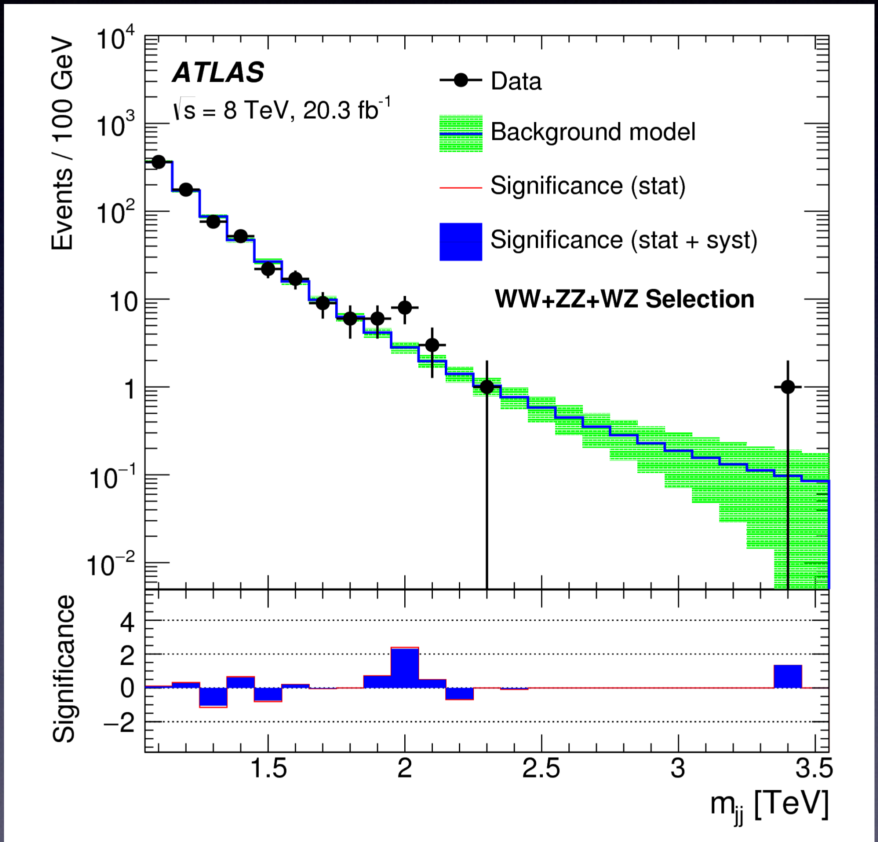




Dibosons in Run1

- The search for WW/WZ/ZZ → *qq*+*qq* in Run1 showed an excess near 2 TeV:



Excess most significant in mass window optimized for *WZ*:

3.5σ local , 2.5σ global

JHEP 12 (2015) 55

- Obvious question: does this persist in Run2?

Dibosons (all hadronic)

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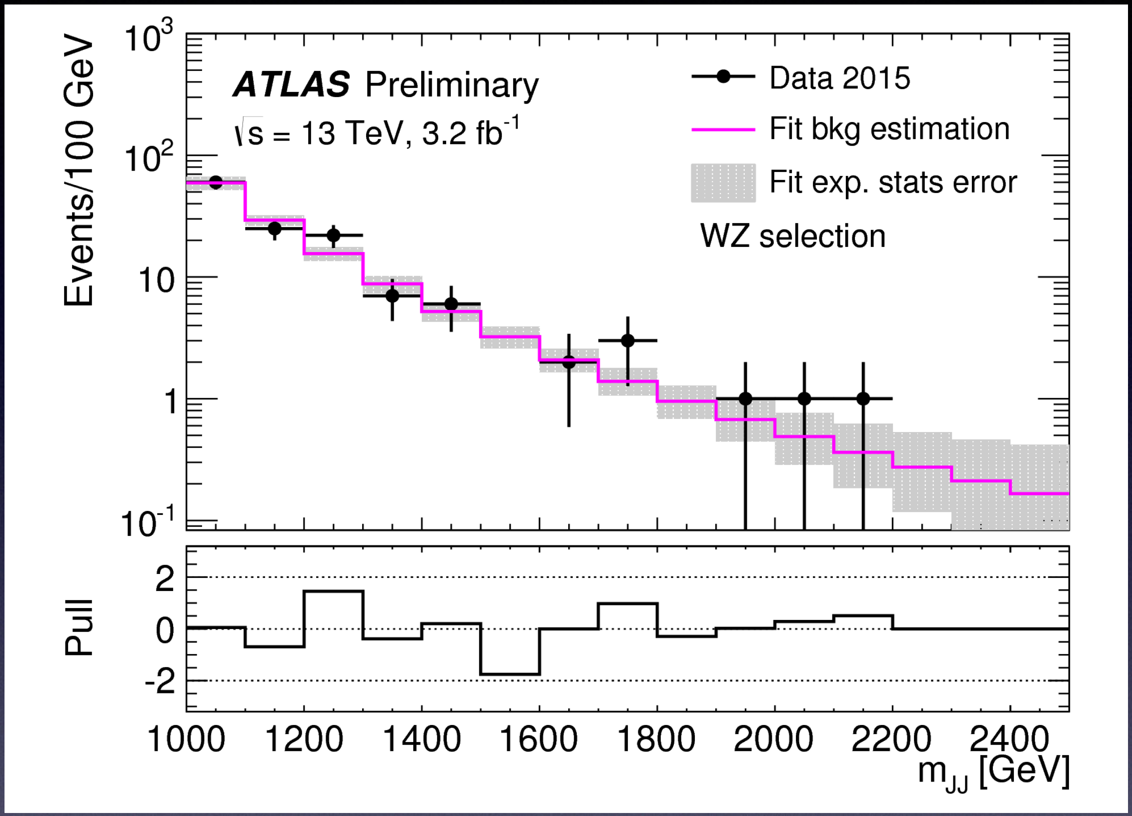
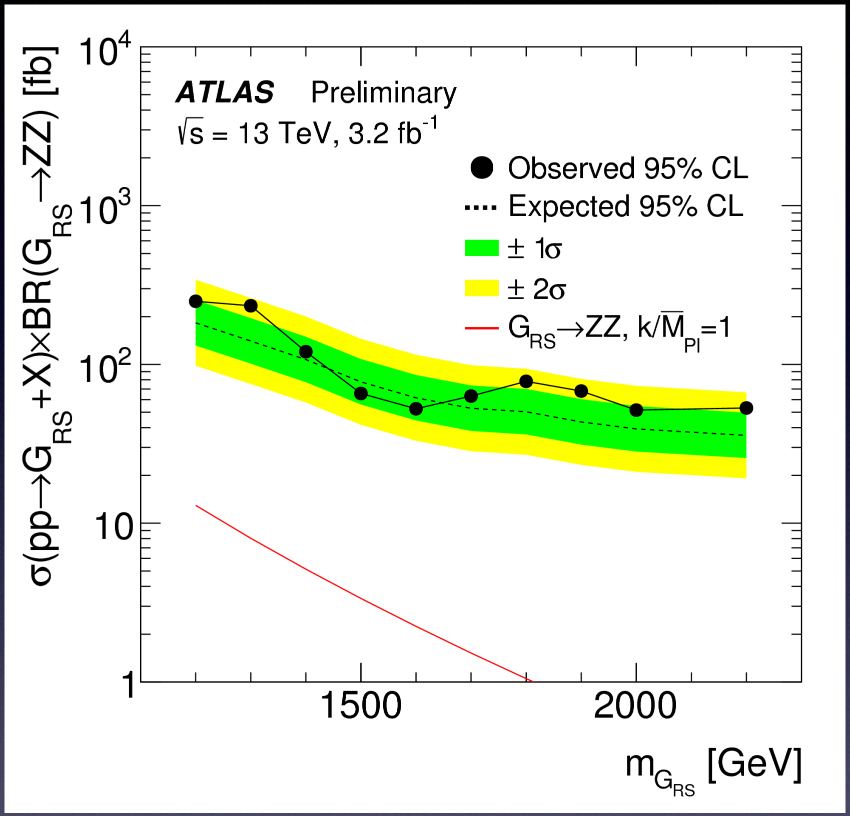


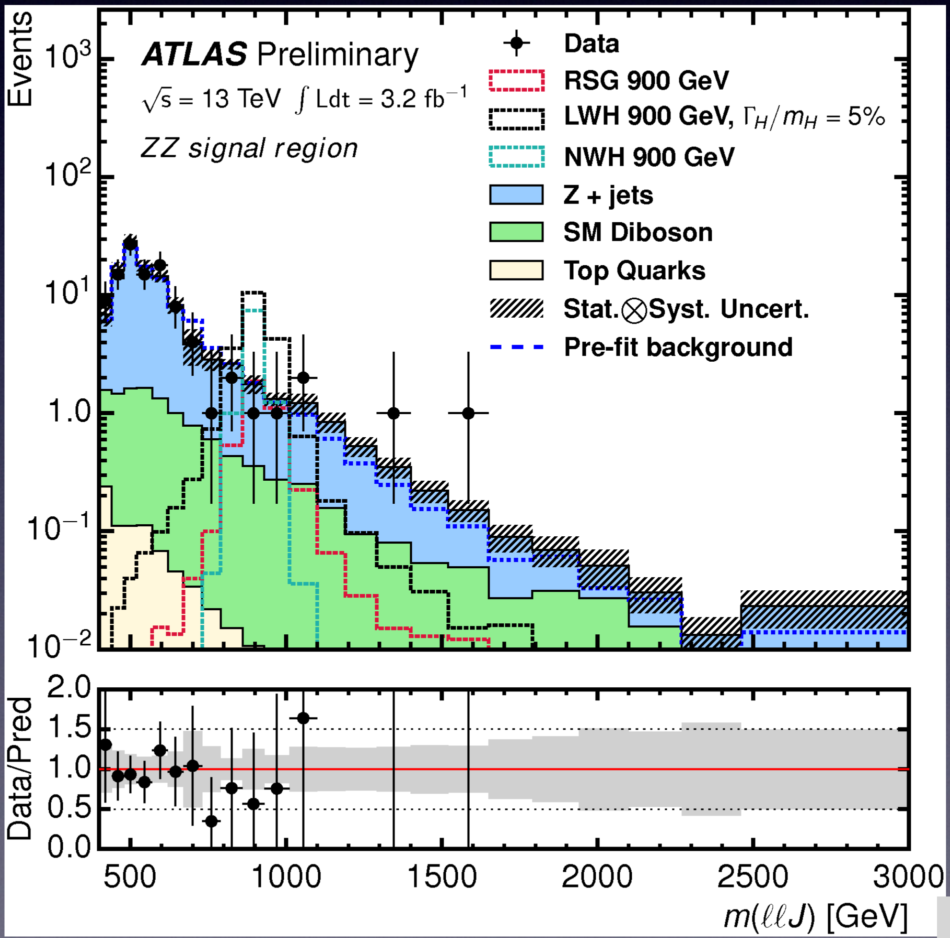


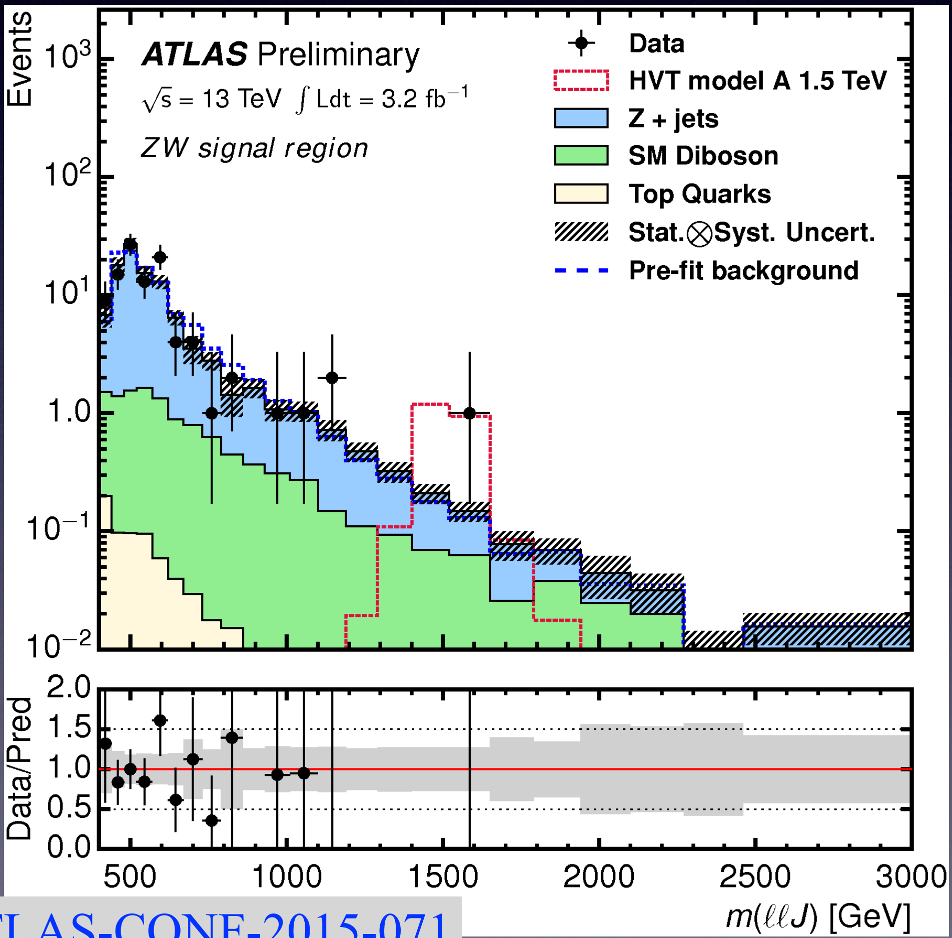
Agreement is similar with *J* mass selection optimized for *WW* and *ZZ*

- No 2 TeV excess, but too soon to draw conclusions…

Dibosons ($ZZ/WZ \to \ell\ell qq$)

- Require ee pair with $83 < m_{ee} < 99$ GeV or $\mu^{\pm}\mu^{\mp}$ pair with $66 < m_{\mu\mu} < 116$ GeV
- $\ell\ell J$ mass distributions





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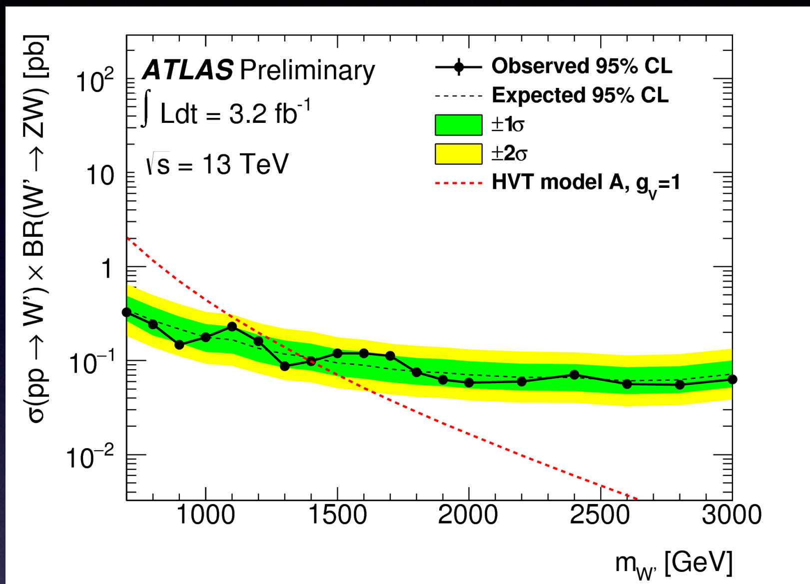
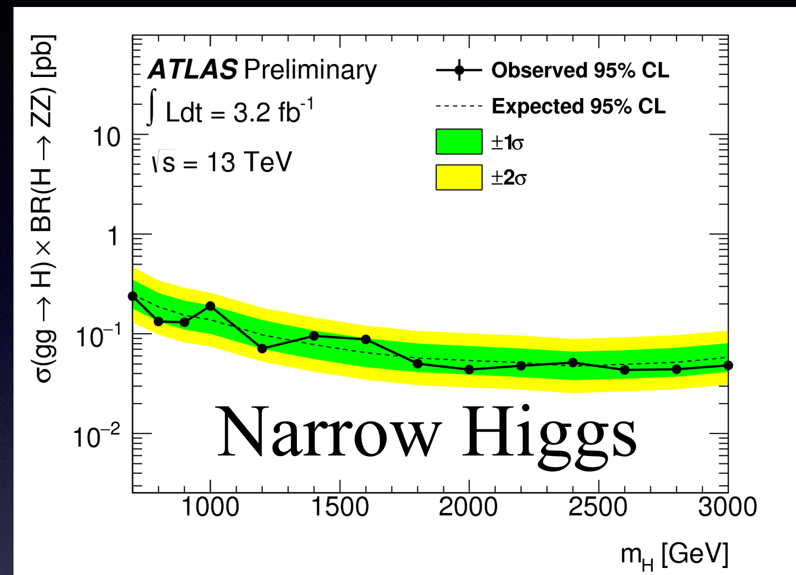
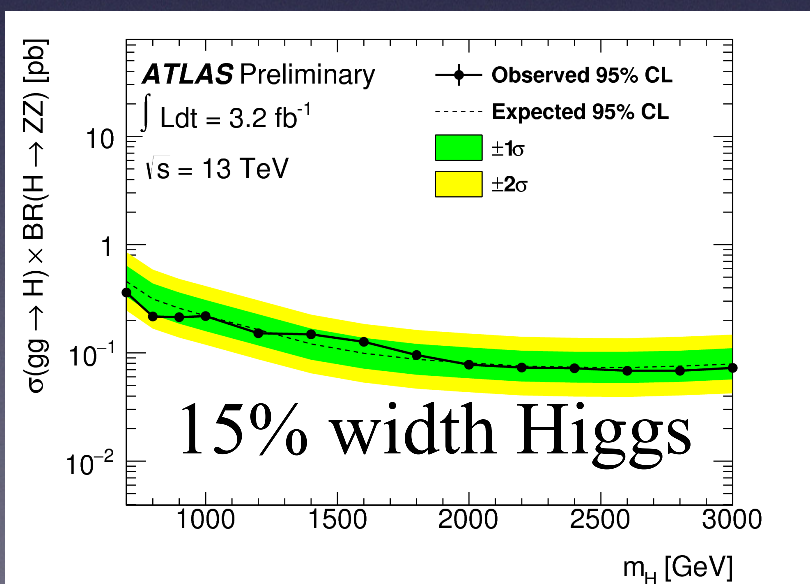
Dibosons ($ZZ/WZ \rightarrow \ell\ell qq$)

- 95% C.L. limits set using CLs method







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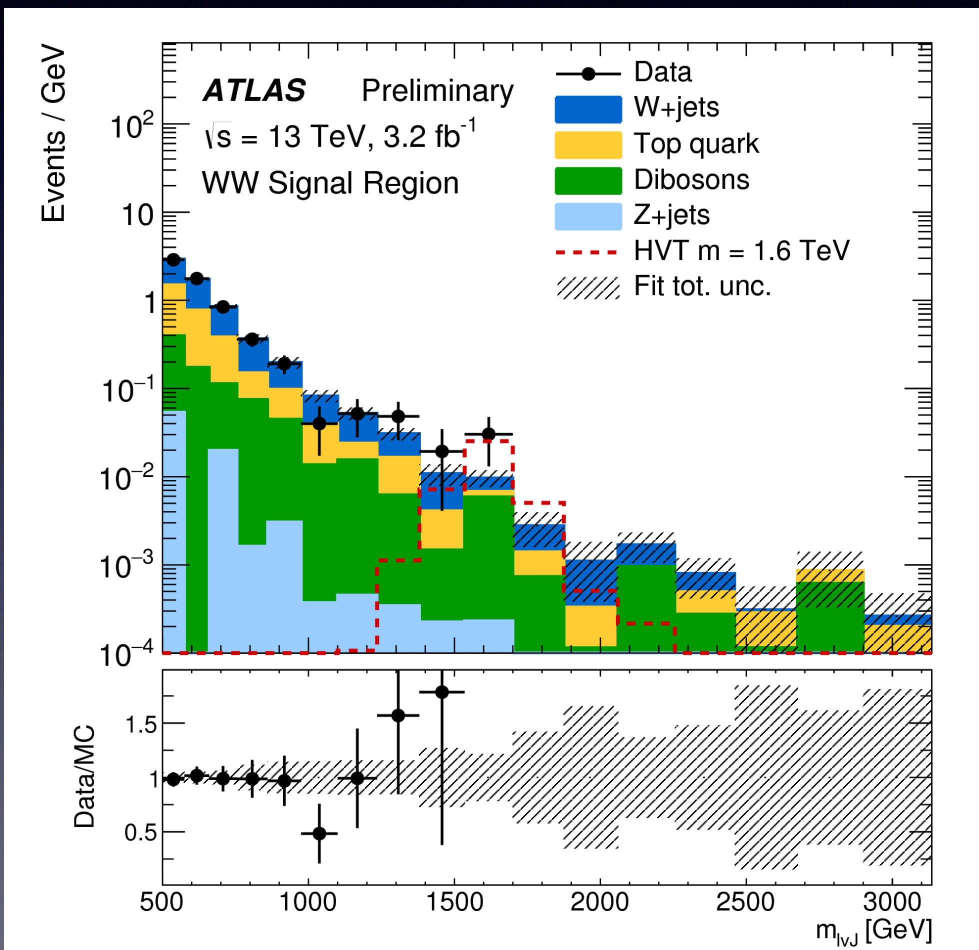
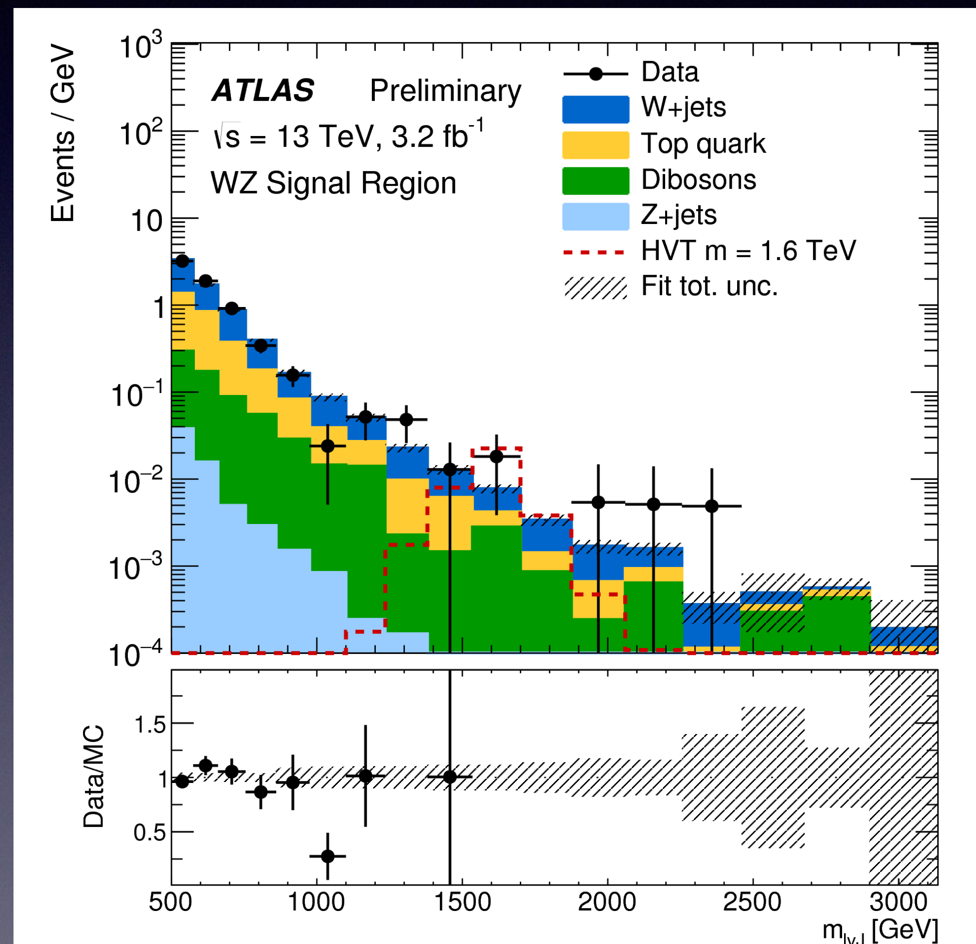
Wider Higgs bosons already excluded in most models

Dibosons ($WW/WZ \rightarrow \ell\nu qq$)

- p_Z of neutrino determined using W mass constraint
  - ambiguity broken by choosing smallest $|p_{z\nu}|$ solution





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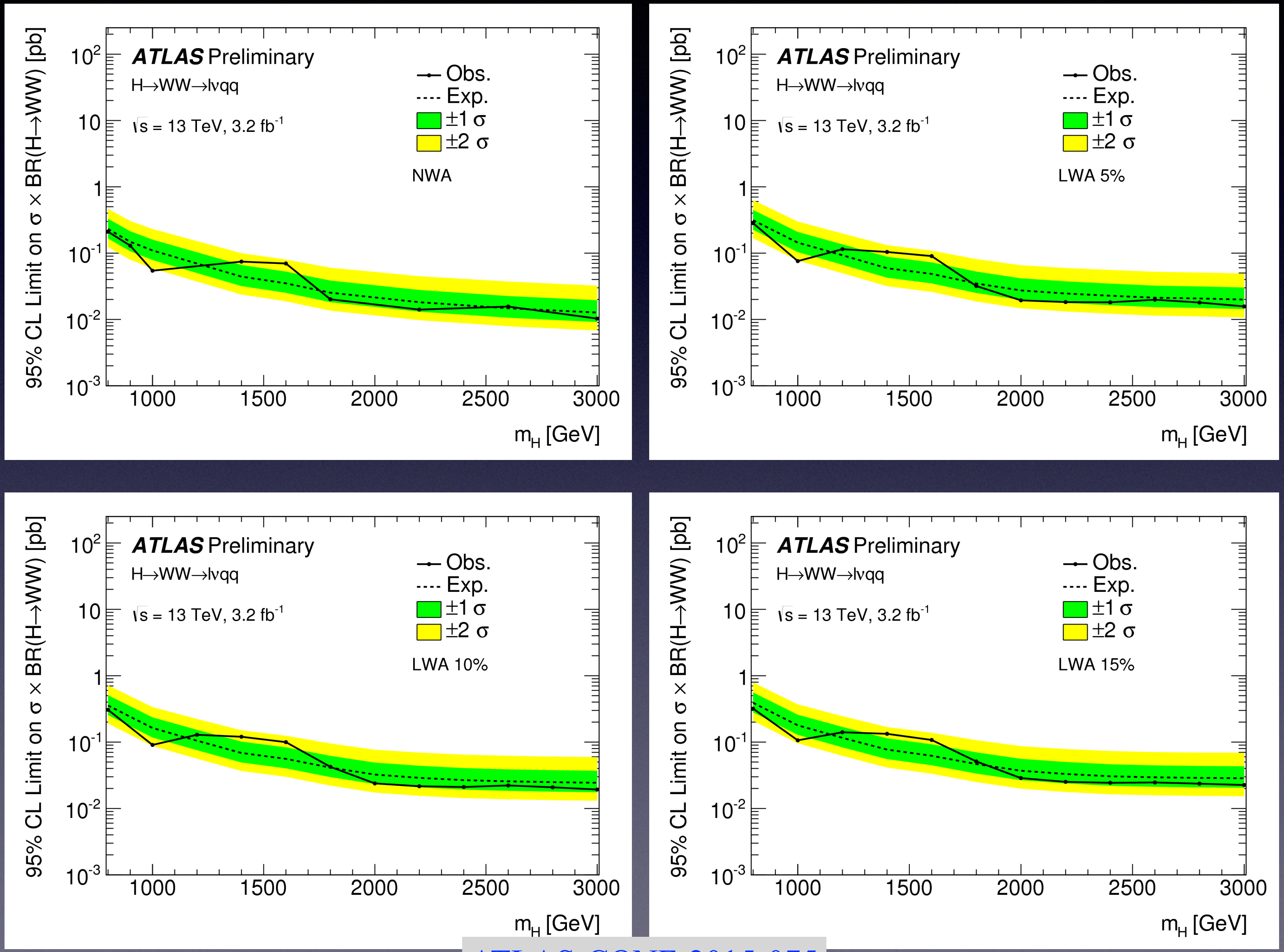
Dibosons ($WW/WZ \rightarrow \ell\nu qq$)

- Limits in the context of heavy Higgs models



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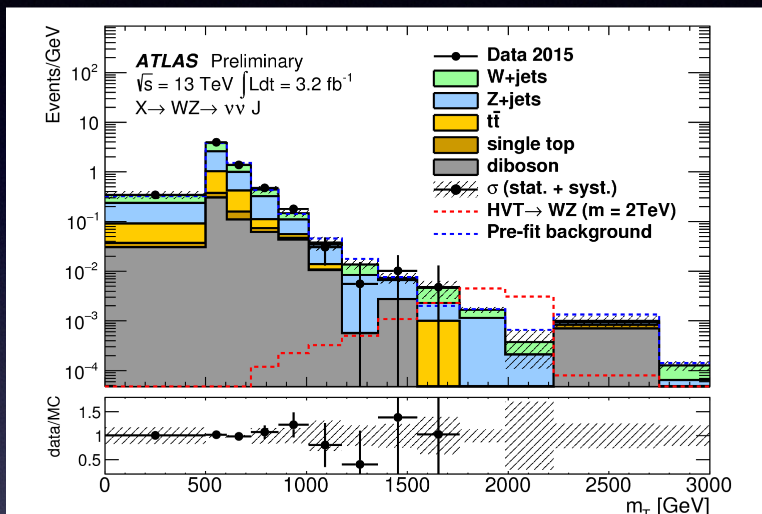
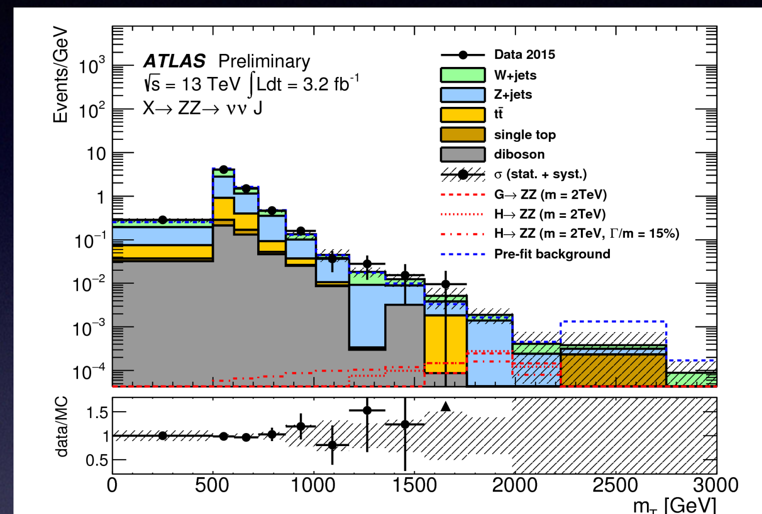
Dibosons (*WZ/ZZ* → νν*qq*)

- Reconstructed as MET recoiling against a single $R = 1.0$ jet
- Transverse mass distribution used to search for signals:





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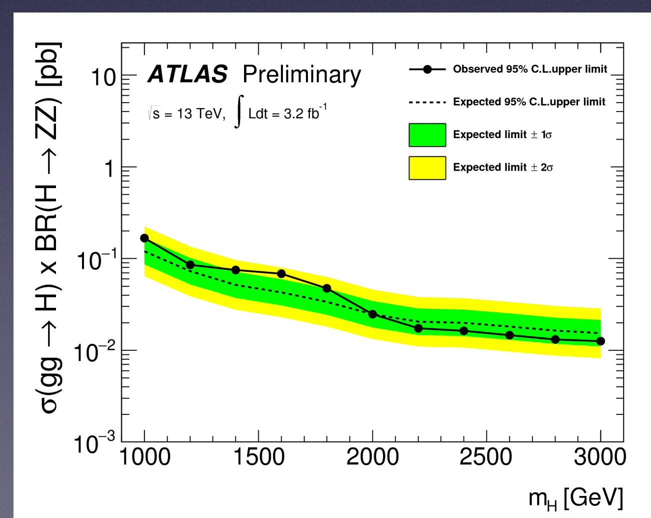
Limits on narrow Higgs benchmark model:



Dibosons (*W*/*Z*+Higgs)

- Vector boson decays to $\ell\nu$, $\ell\ell$, and $\nu\nu$ considered
- Higgs decays to *bb*

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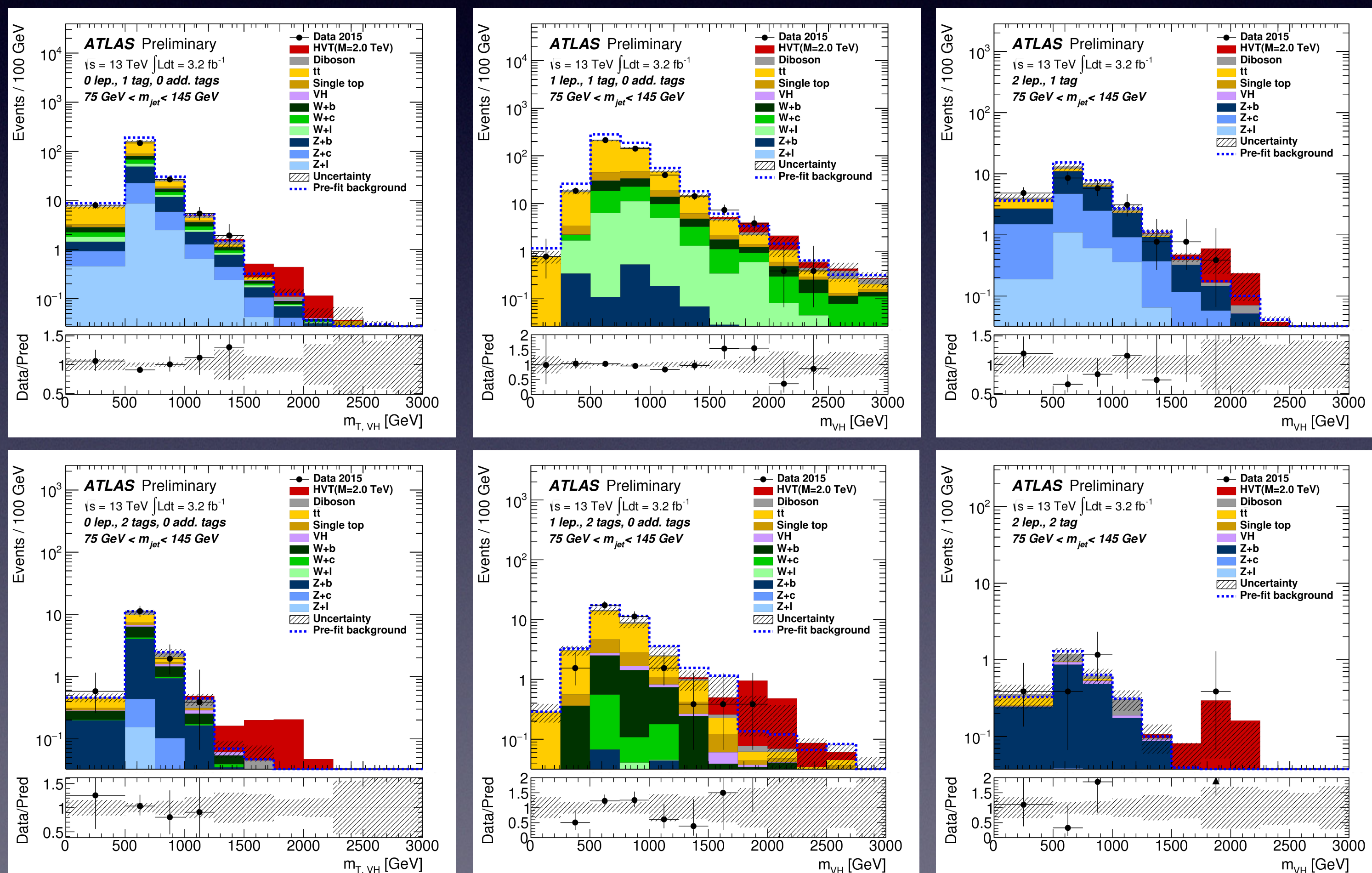
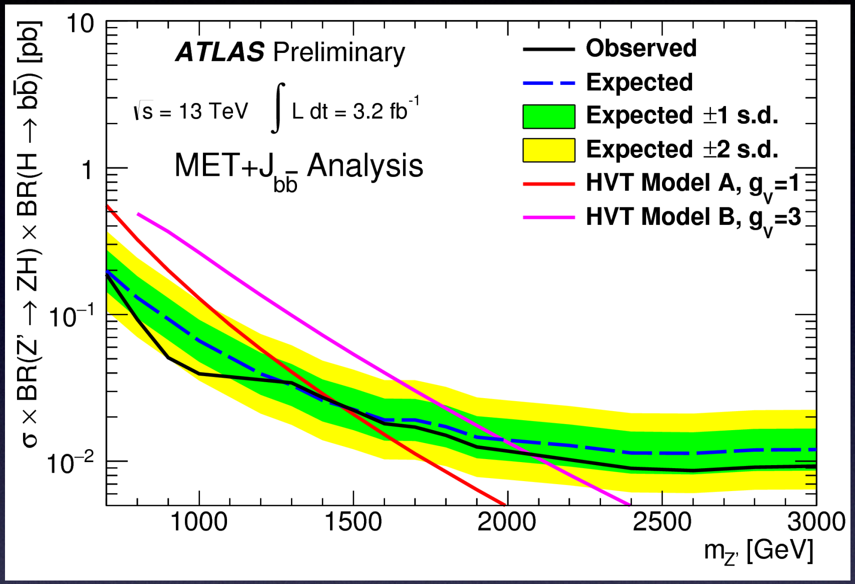
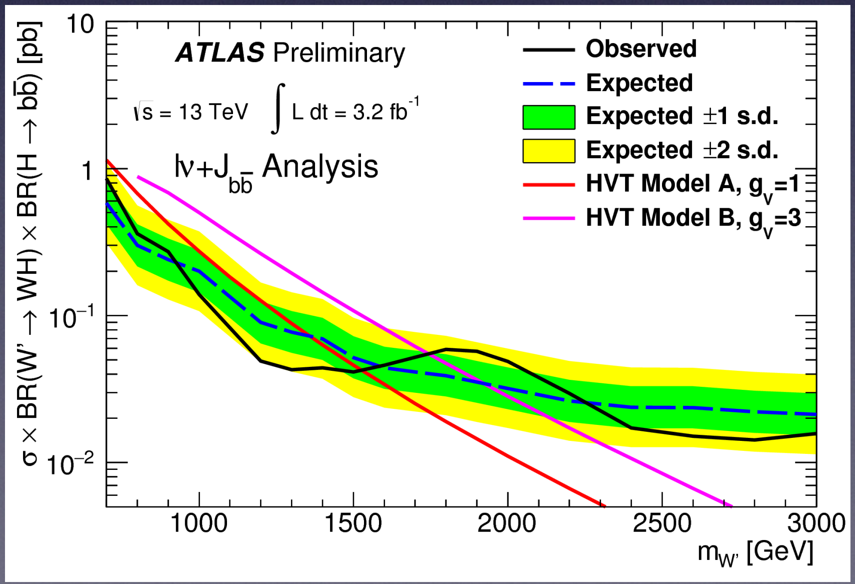
	$\nu\nu$	$\ell\nu$	$\ell\ell$
1 *b* tag			
2 *b* tags			



Dibosons (*W*/*Z*+Higgs)

- Limits for the three lepton multiplicities





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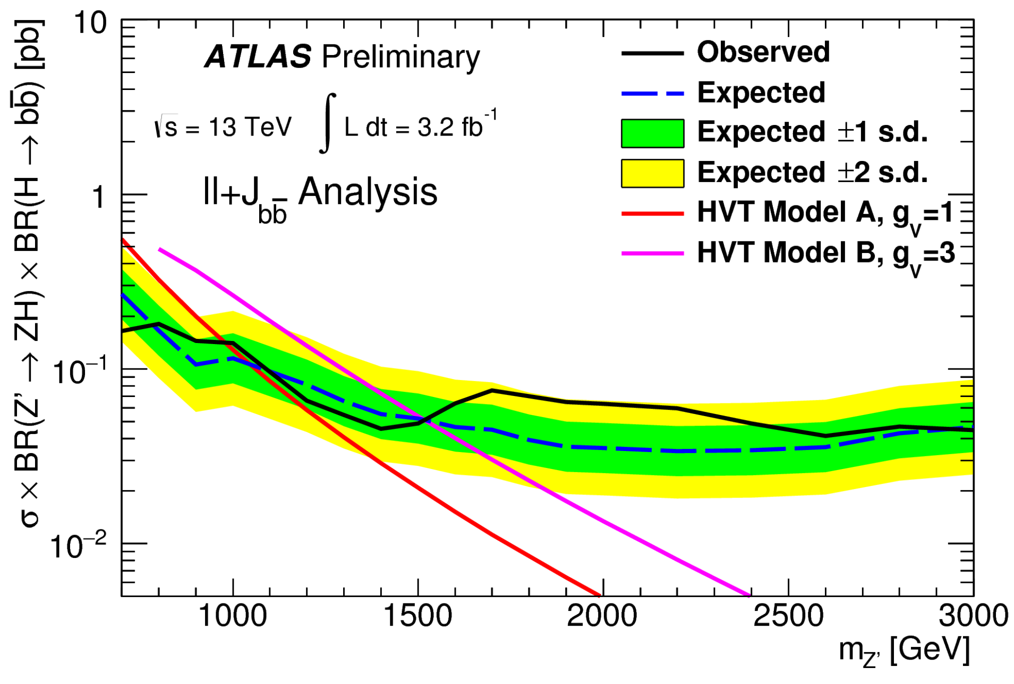
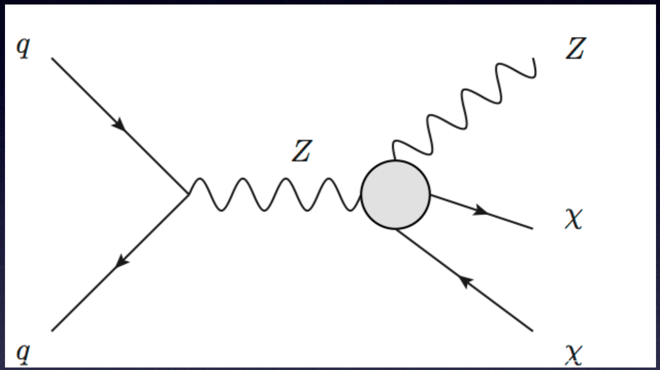
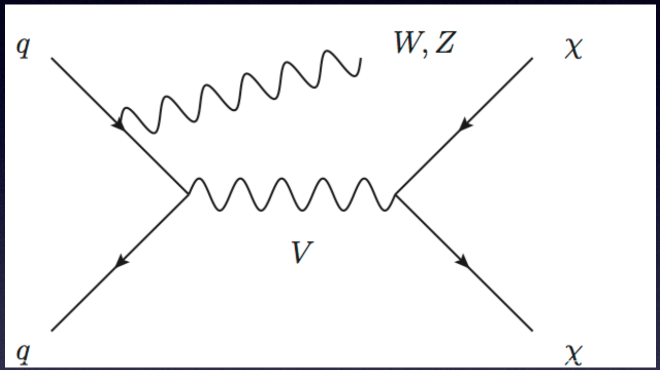


Dark Matter in MET+*W*/*Z*

- Motivation is to search for dark matter (χ) particles produced in association with a *W* or *Z* boson
- Benchmark models:



EFT with $ZZ\chi\chi$ vertex



Vector mediator

- χ appears as MET
- *W*/*Z* reconstructed using hadronic boson tagging methods

Dark Matter in MET+W/Z

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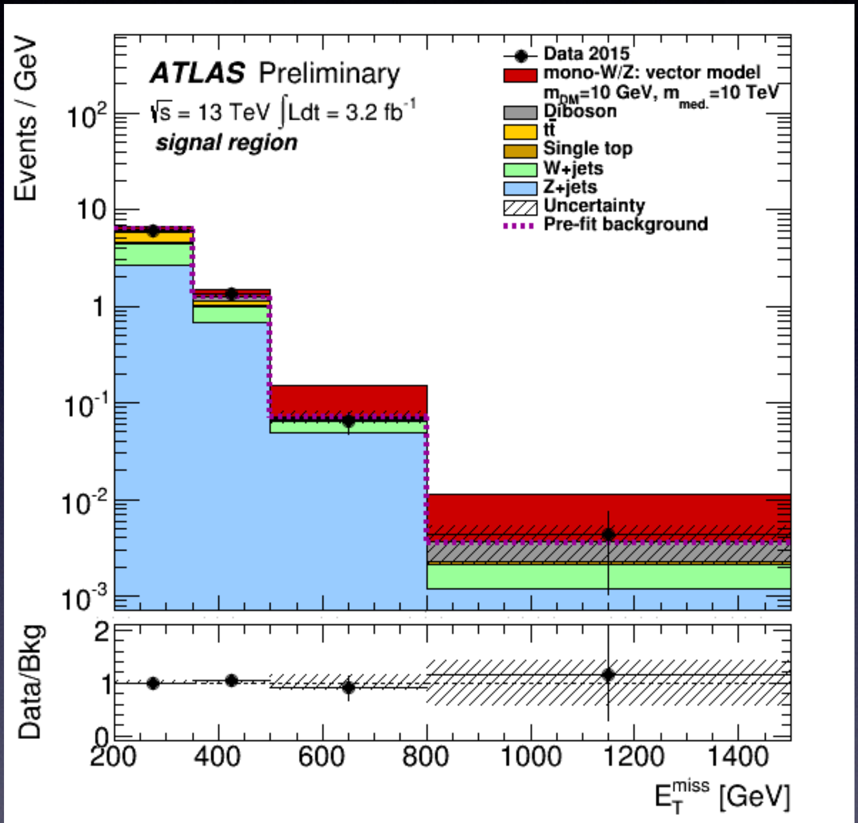
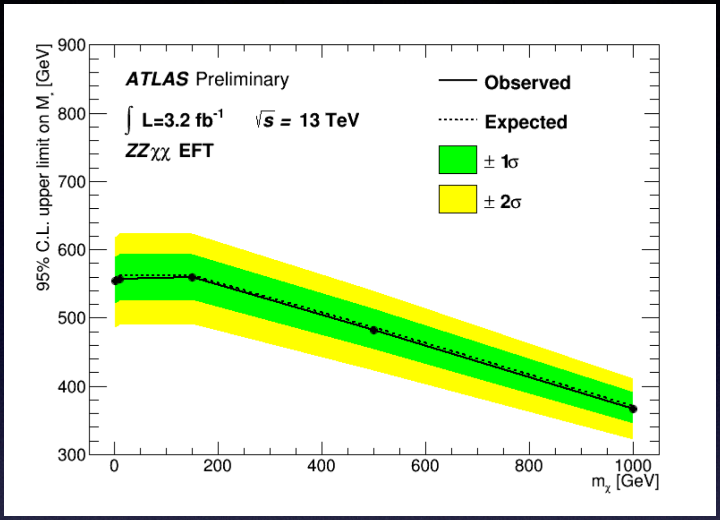
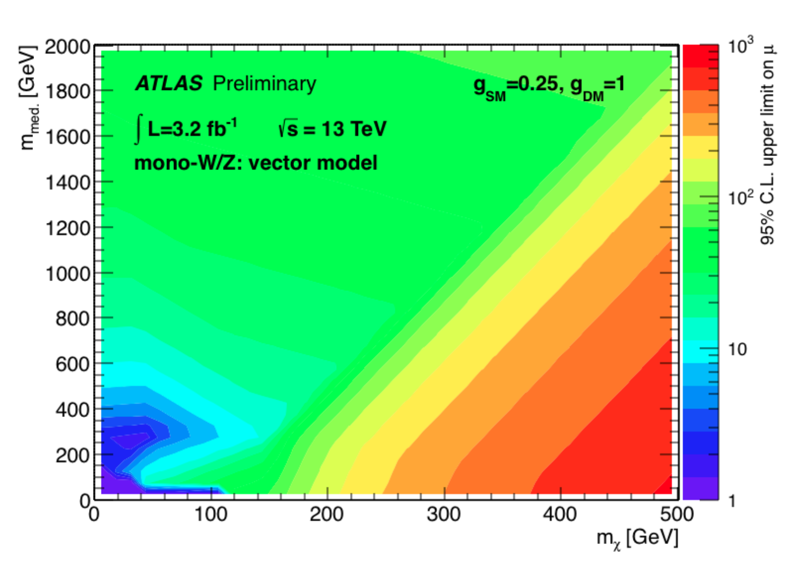
MET distribution



Limits on $ZZ\chi\chi$ EFT

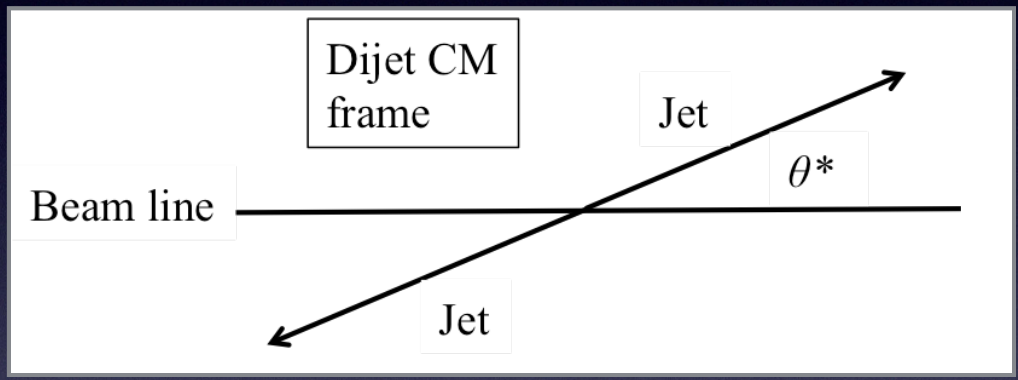


Limits on Vector Mediator



Dijet Searches

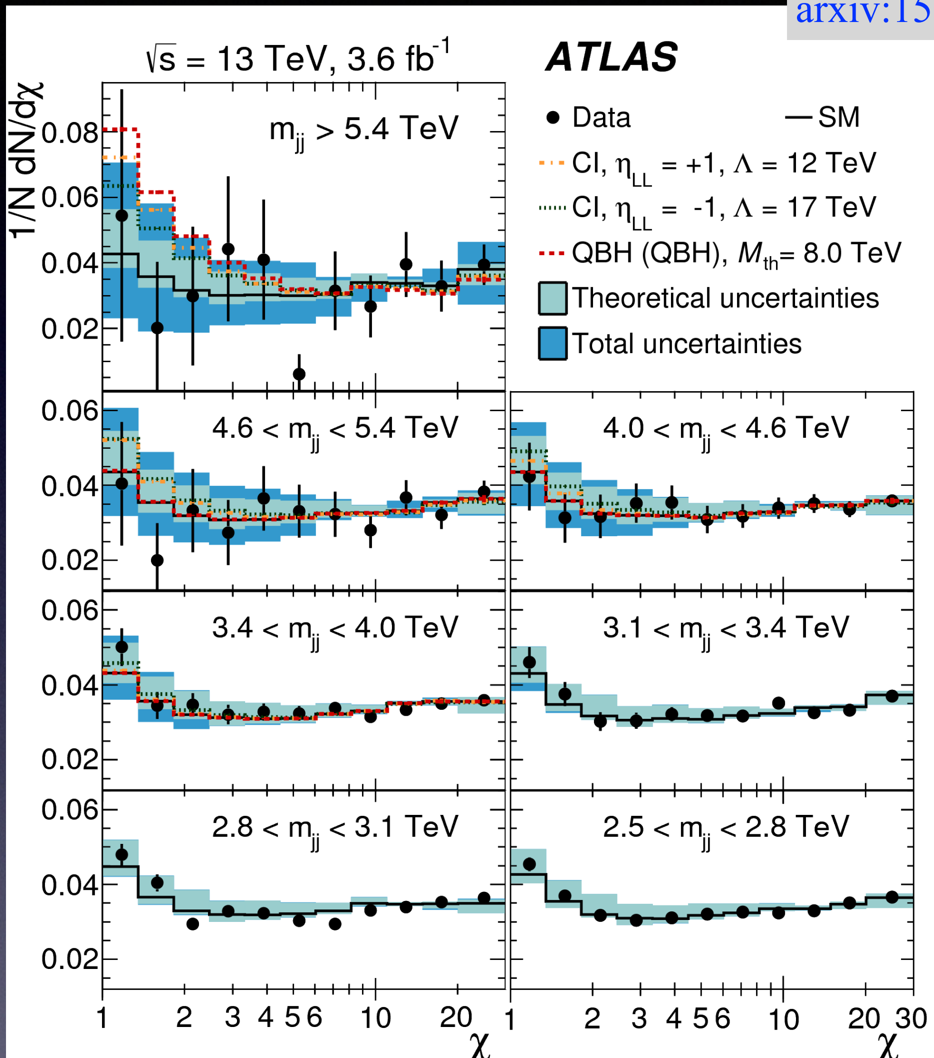
- Two variables used in dijet searches
  - dijet mass m_{jj} and $\chi = e^{(|y_1 - y_2|)} = e^{2|y*|} \sim \dfrac{1+\cos\theta^*}{1-\cos\theta^*}$

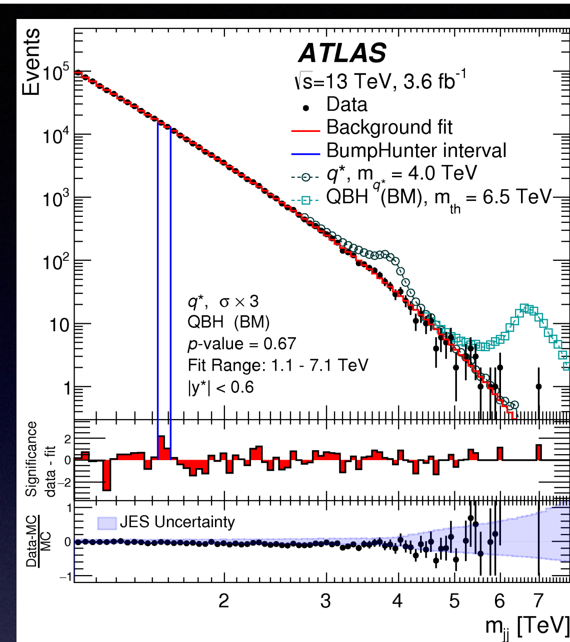


    - ✦ χ is Lorentz-invariant, and distribution is ~uniform in SM
- Sensitive to new particles in s- and t-channels, respectively
  - any new particle produced at the LHC must couple to quarks/gluons
  - dijet search is sensitive to all such particles

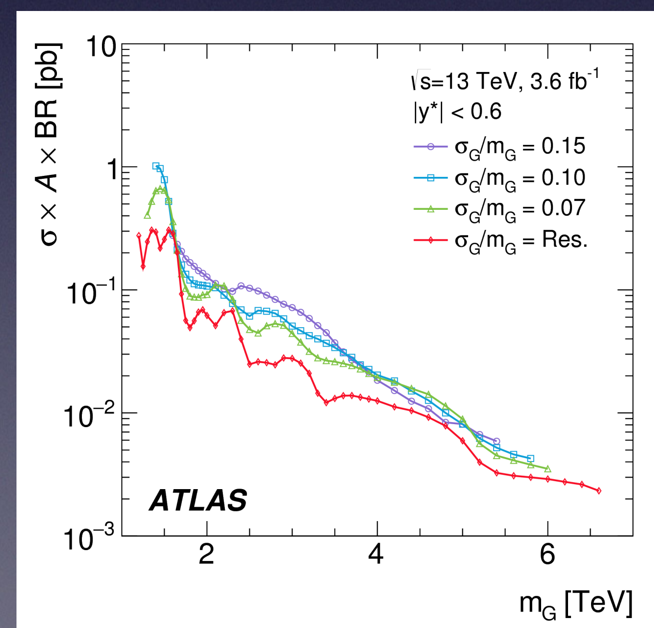
Dijet Searches

arxiv:1512.01530





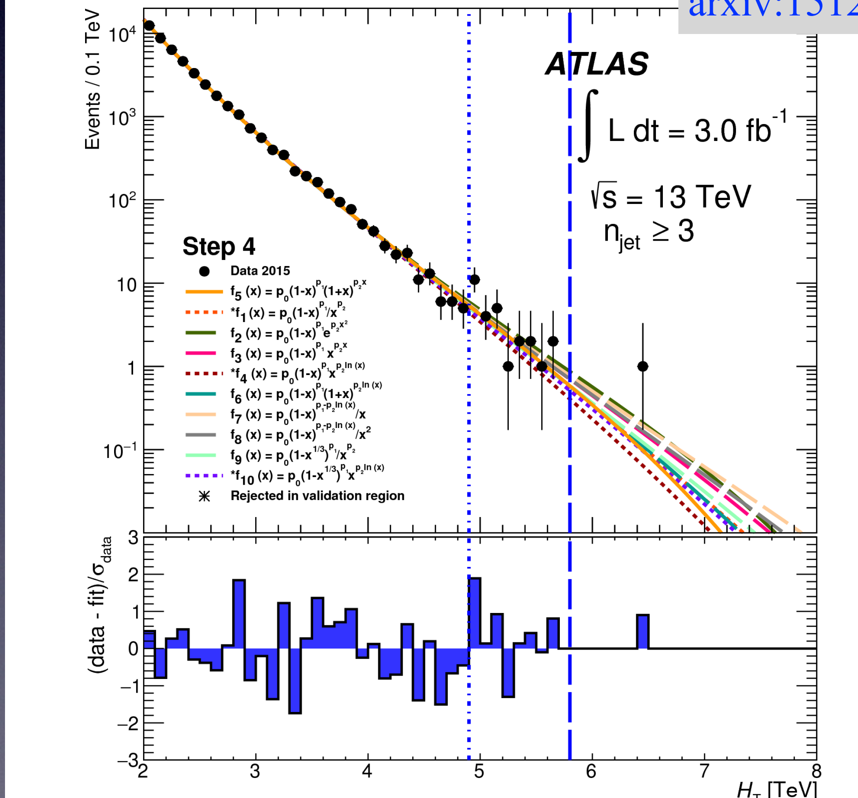
Limits on benchmark Gaussian signals:

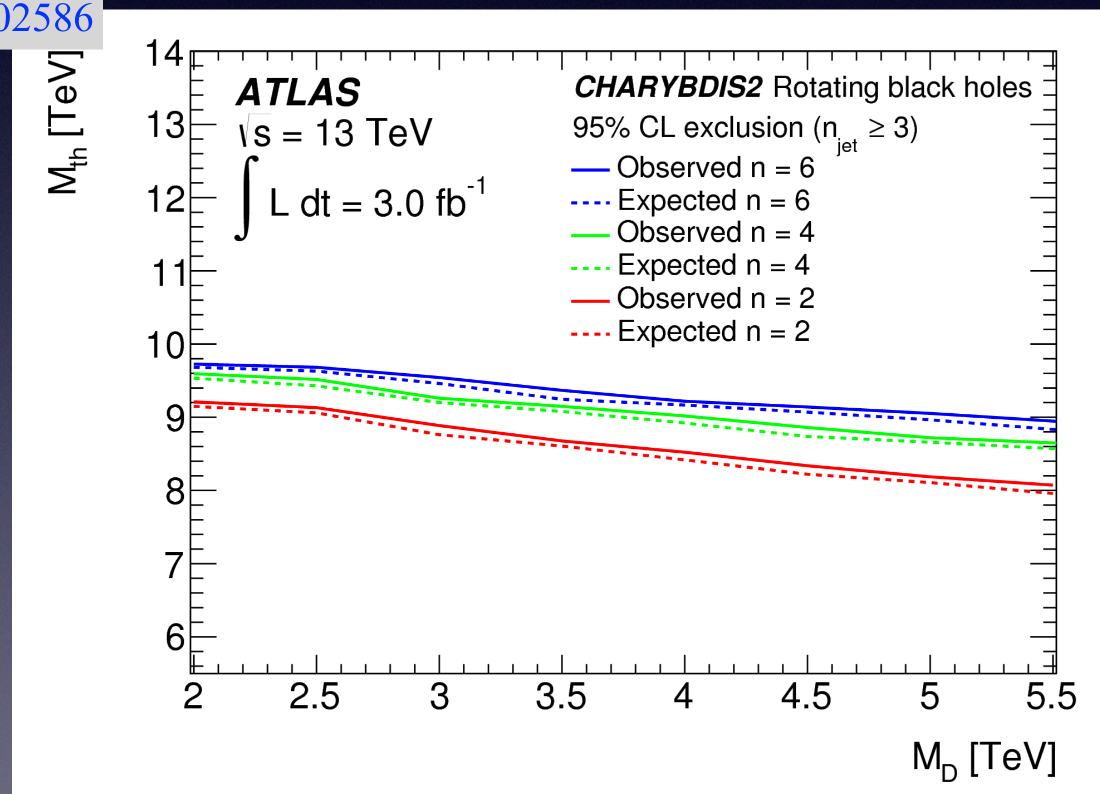


Multijet Searches

- Motivated by strong gravity effects (e.g. black holes or string balls) decaying to jets
- Require at least 3 jets with $H_T = \Sigma$(jet pt) > 1 TeV
  - inclusive approach, since number of jets varies stochastically

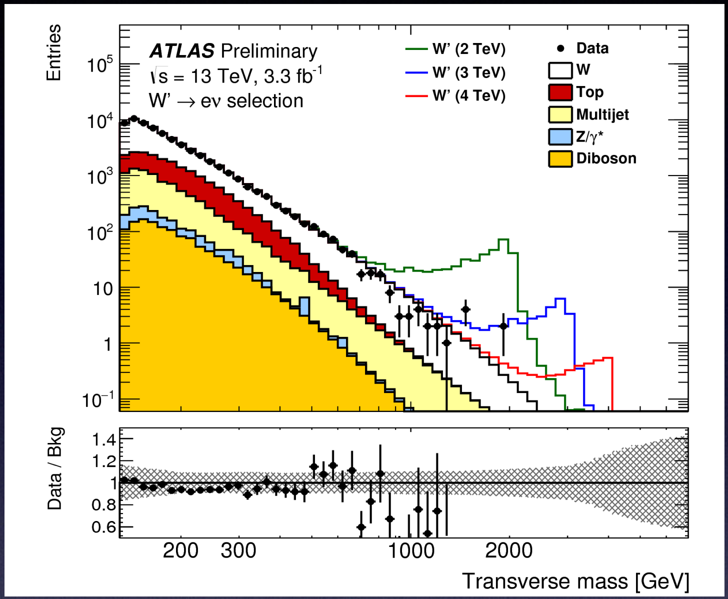
arxiv:1512.02586

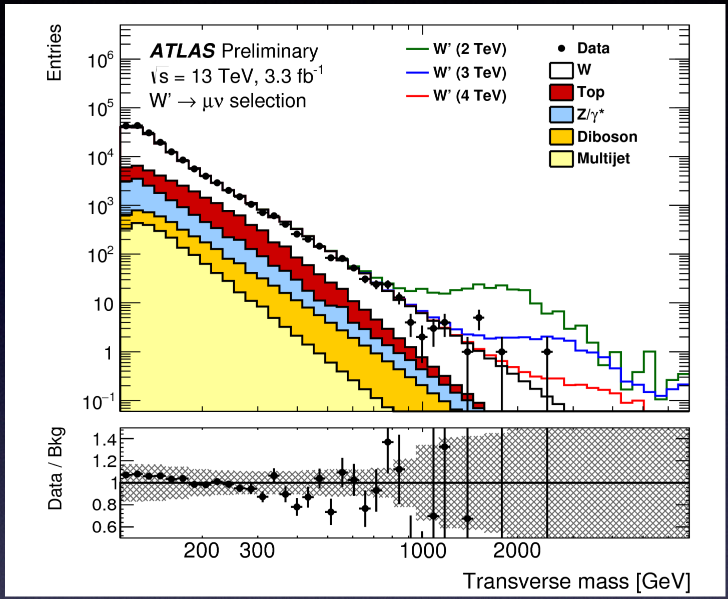




$W' \to \ell\nu$

- Transverse mass distributions in electron and muon channels:





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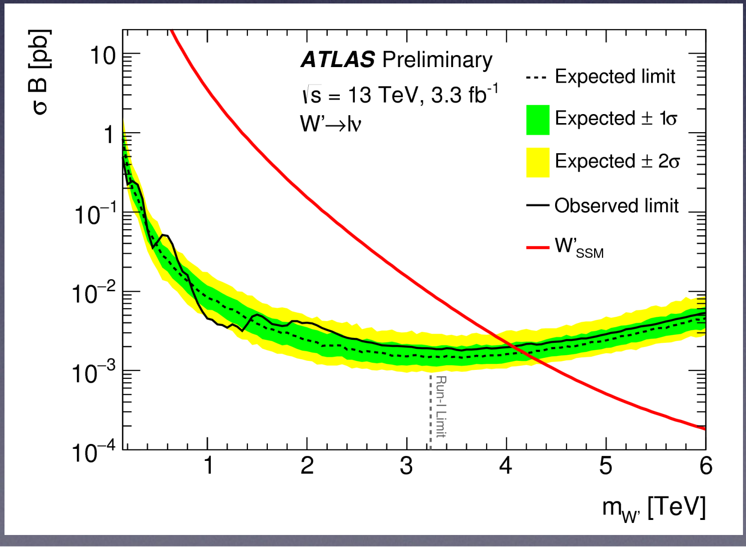
Combined limit for Sequential Standard Model W′:



Opposite-sign dileptons

- New physics could alter the *ee* and *μμ* mass distributions in two ways
  - a new resonance (Z') would create a bump
  - non-resonant effects could change the shape
- *ee* and *μμ* mass distributions:

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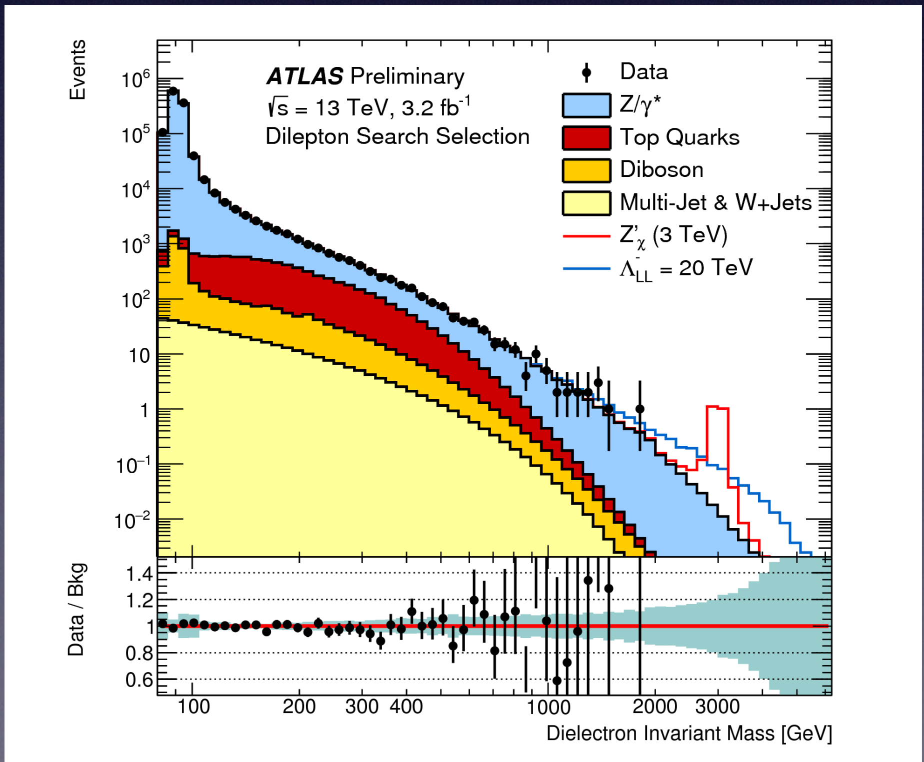
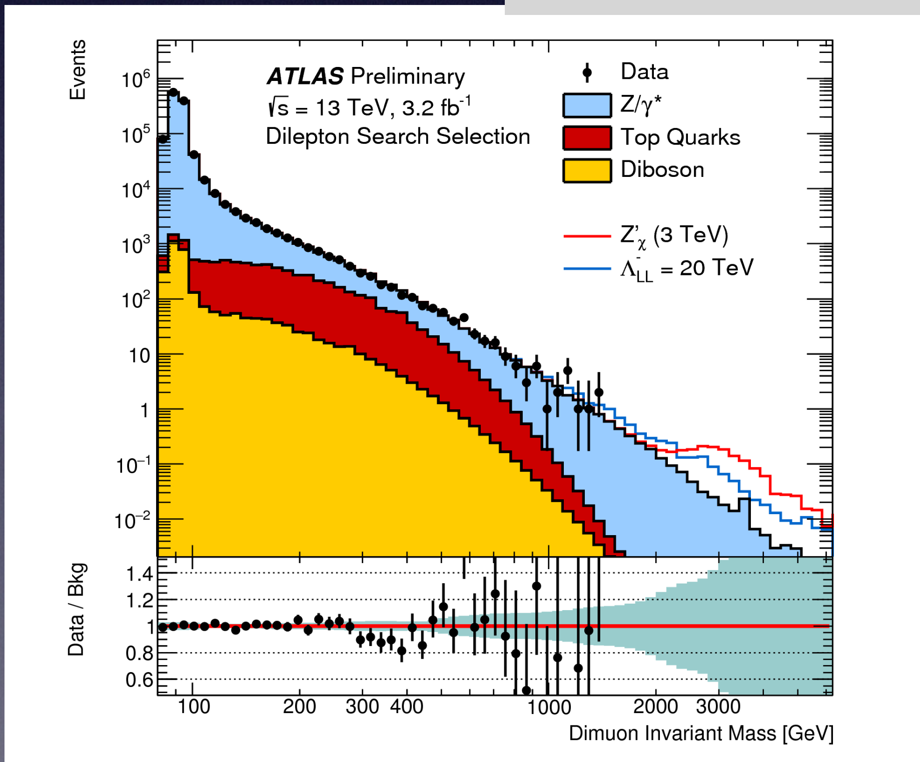
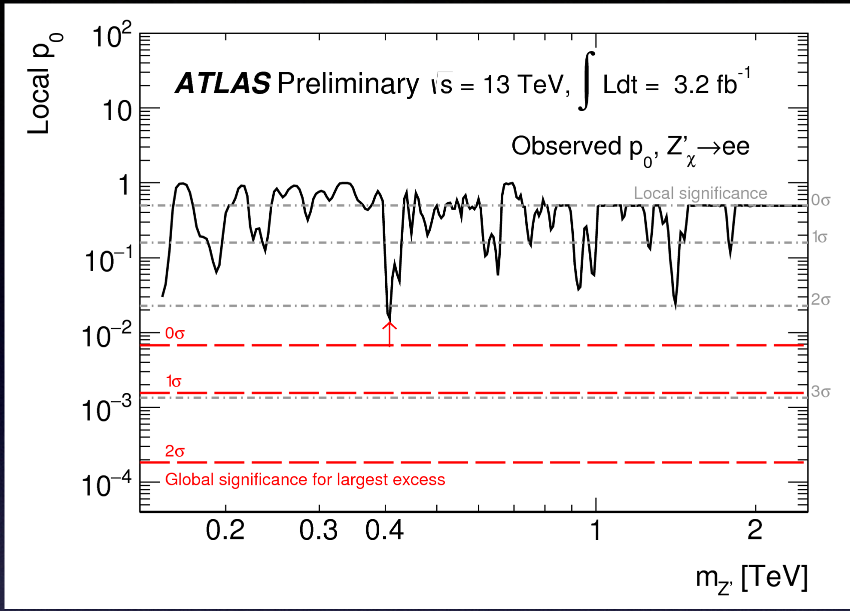
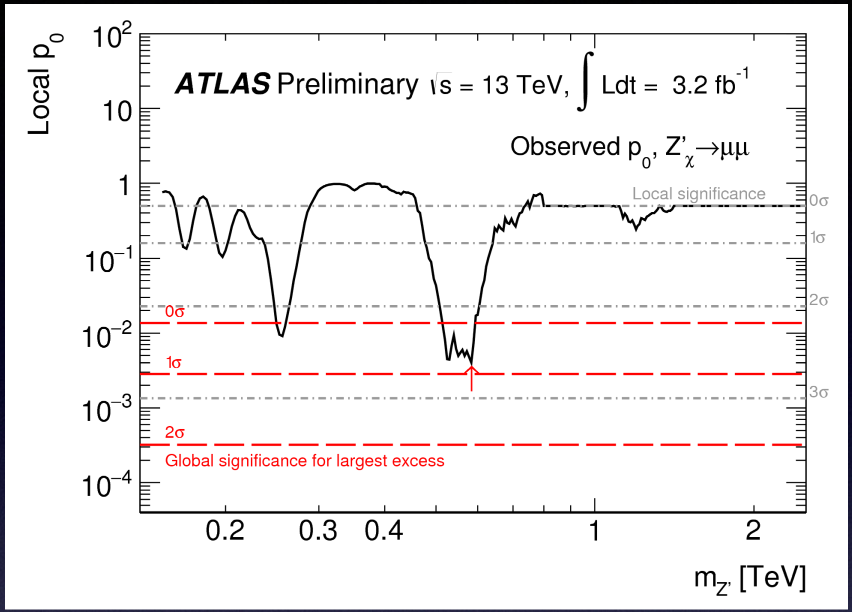




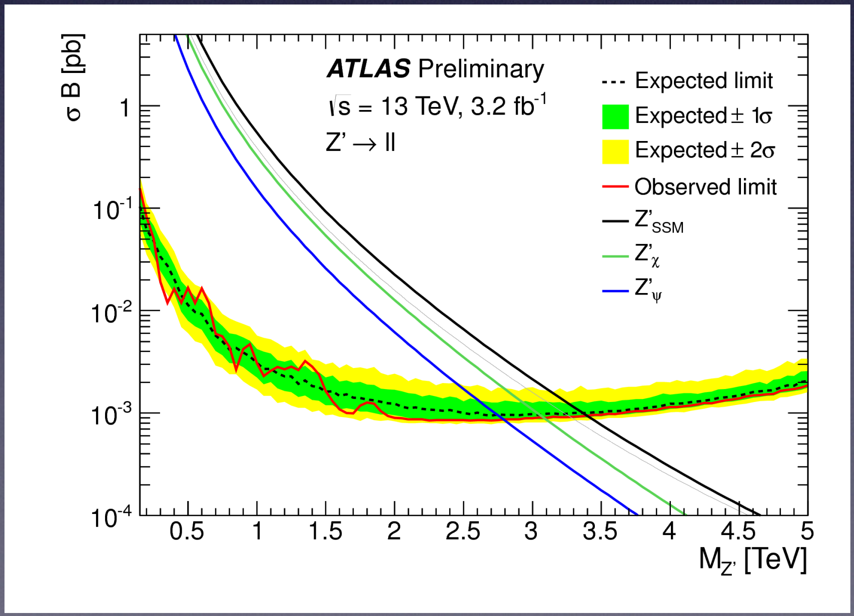
Opposite-sign dileptons

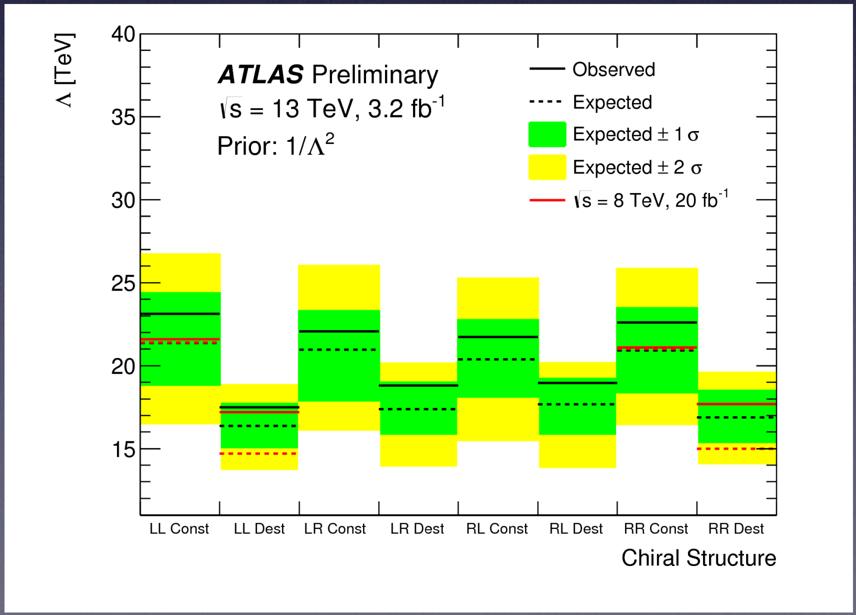
p values:





Z' and contact interaction limits:

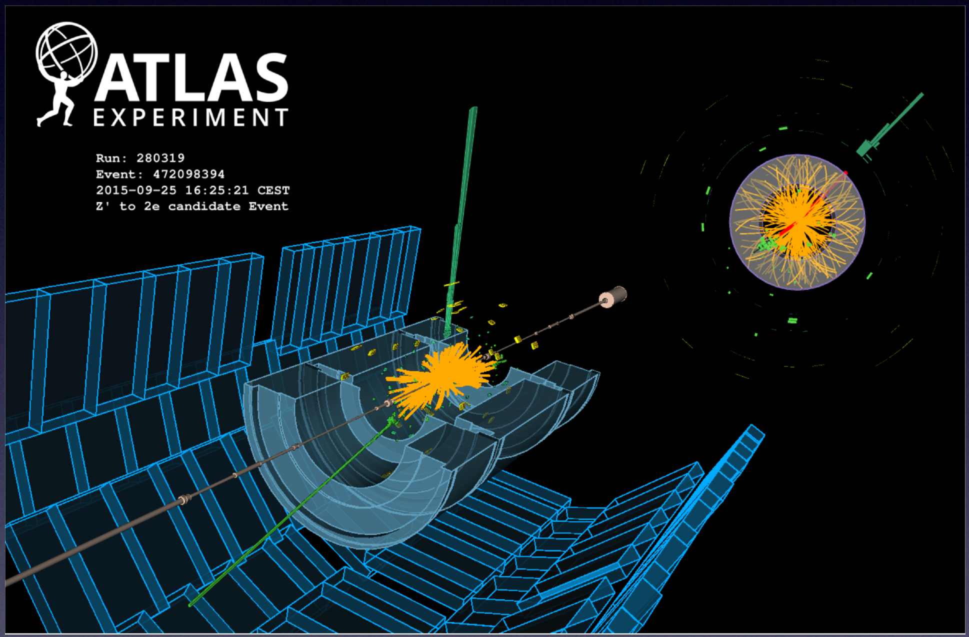




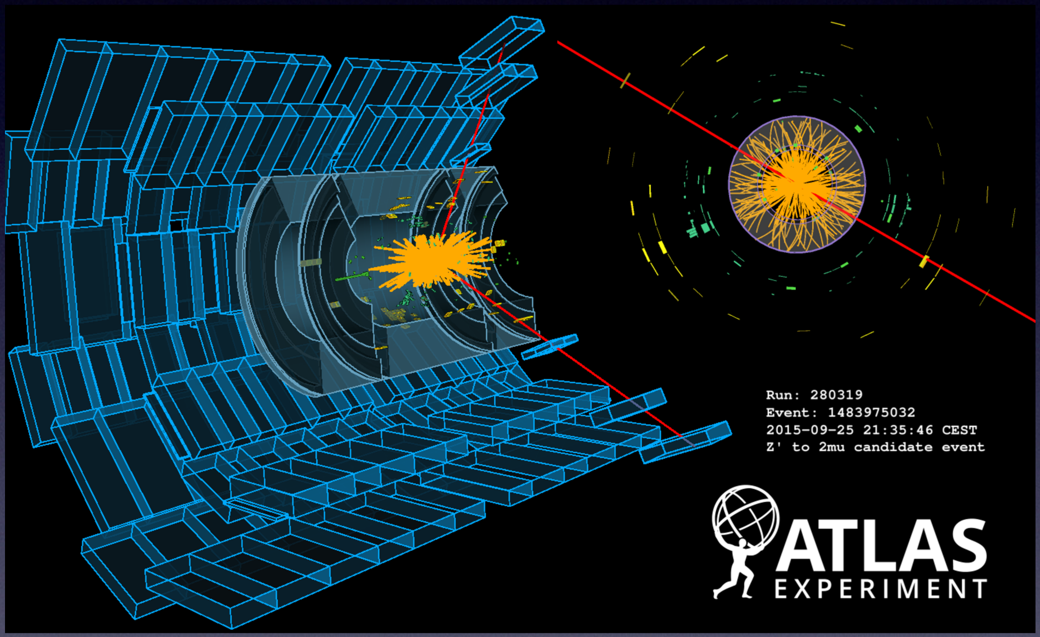
$Z' \rightarrow \ell\ell$

- Event displays of the highest $m_{\ell\ell}$ events:

$m_{ee} = 1775$ GeV



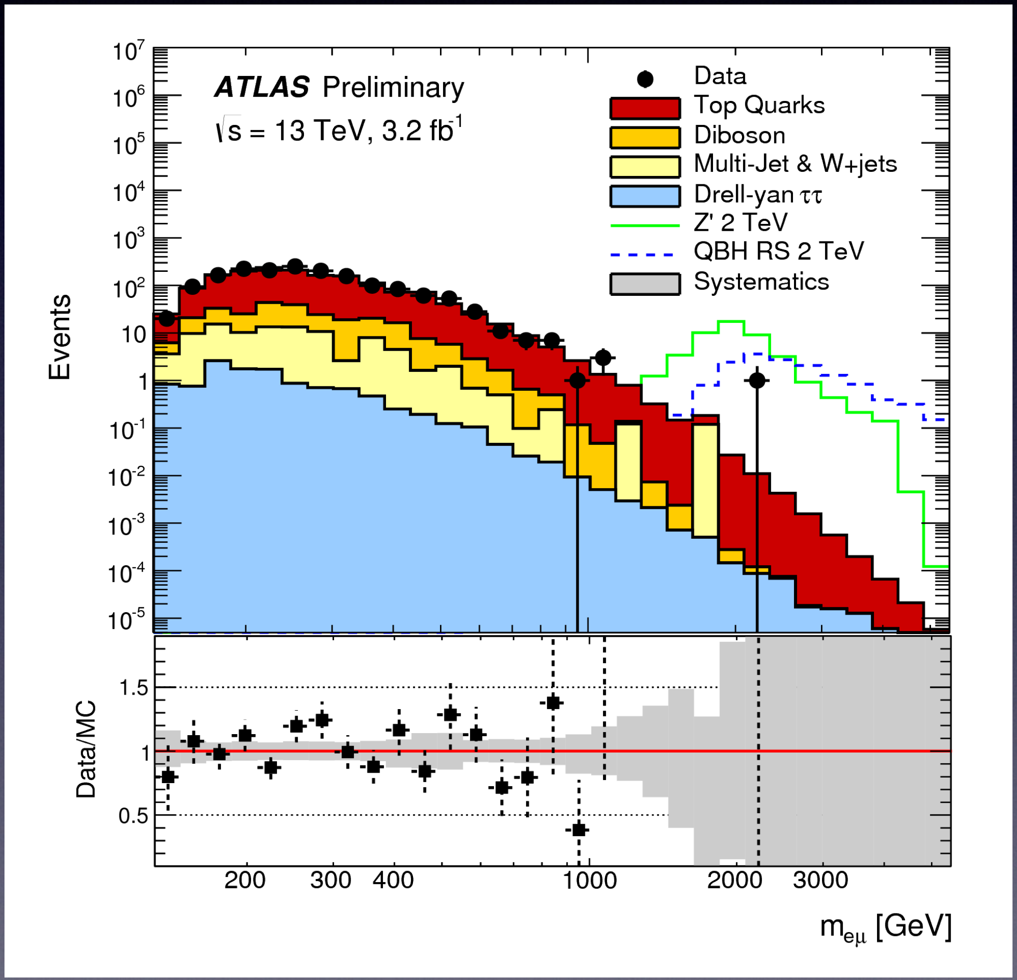
$m_{\mu\mu} = 1390$ GeV

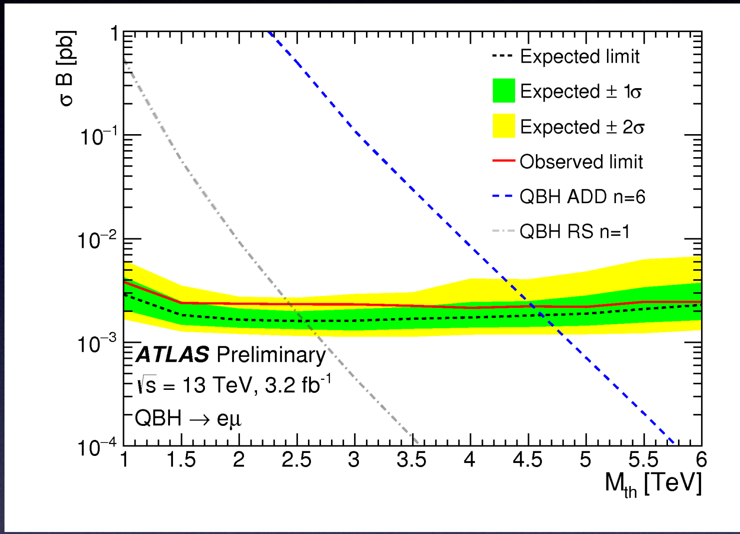


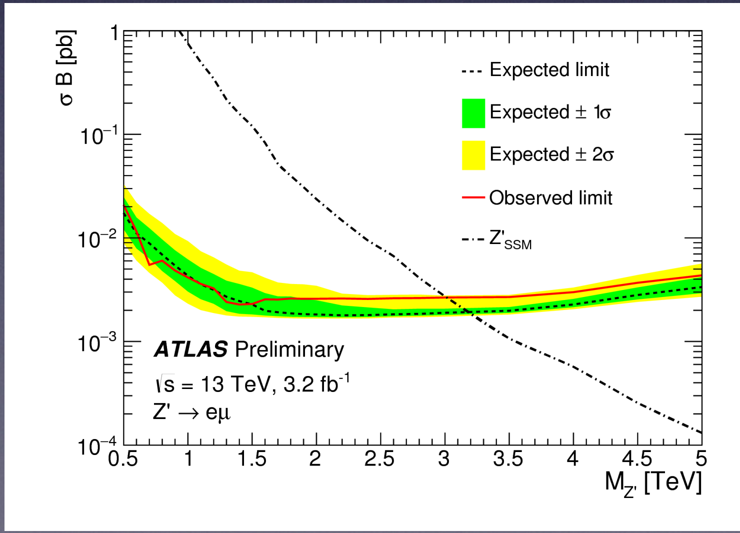
eμ

- Highly sensitive channel for new neutral resonance with lepton-flavor violating decays

ATLAS-CONF-2015-072







Summary

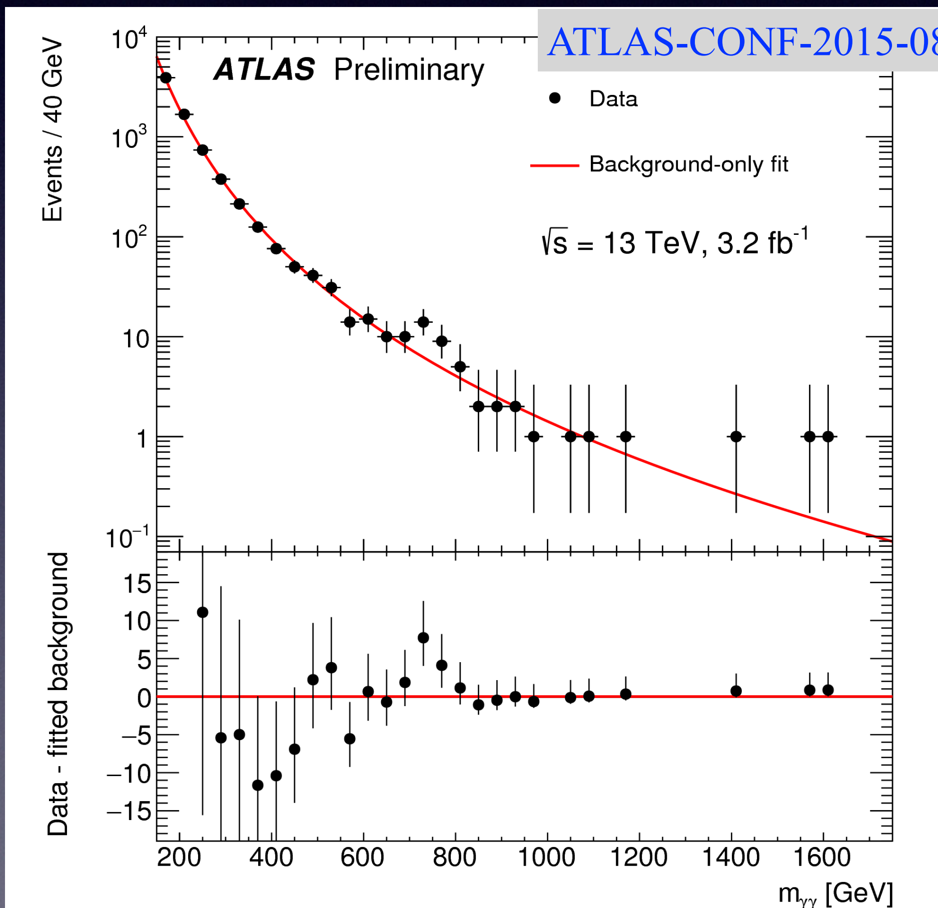
- ATLAS is pursuing a broad search for exotic phenomena
- Some searches have already been updated using the 2015 data
  - thanks to the increased LHC energy, Run 1 sensitivity to many signals has already been exceeded with ~3 fb^{-1}
- Unfortunately, few surprises so far
  - but there is the diphoton excess from M. Scioppa's talk
- Still to come:
  - updated searches for many other new phenomena
  - including follow up on some of the most interesting results from Run 1

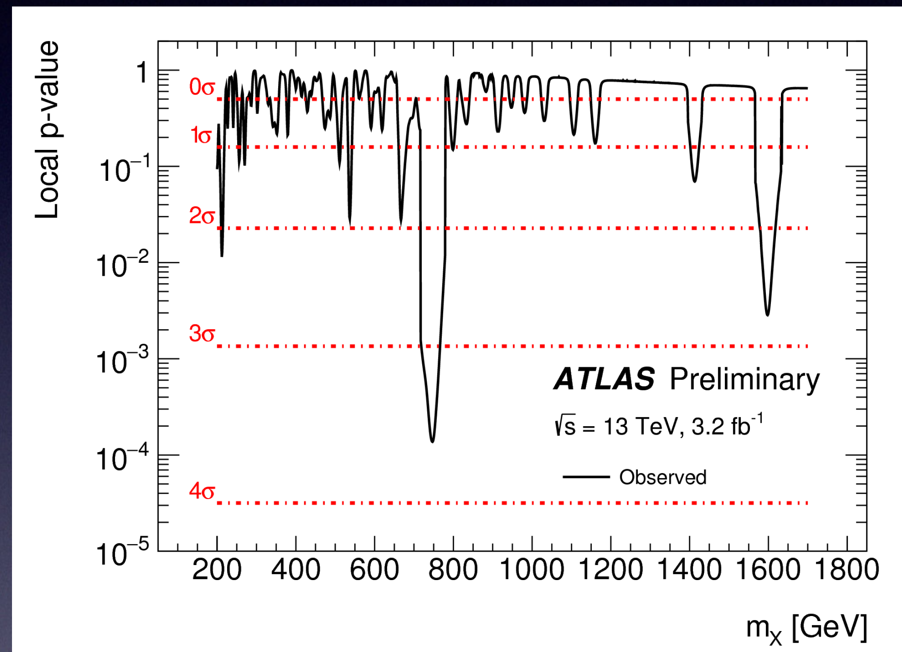
Backup

Diphoton

- Search optimized for scalar resonances
- Background $m_{\gamma\gamma}$ shape fit to empirical function
- Excess seen near 750 GeV:

ATLAS-CONF-2015-081

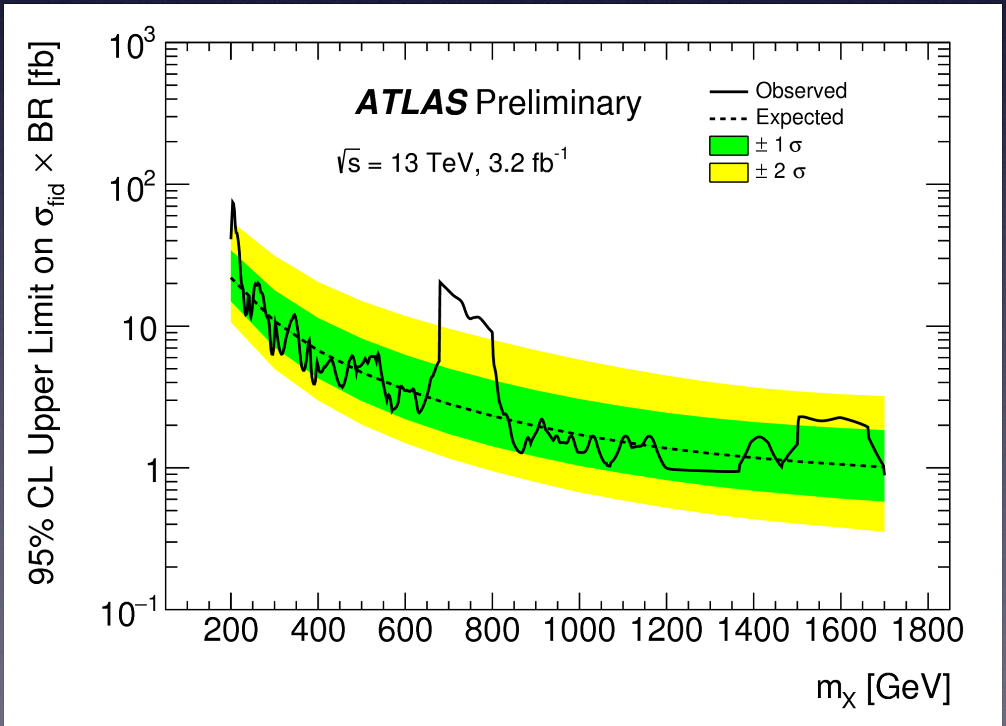




Local significance is 3.6σ
With LEE: 2.0σ

Diphoton

- Other notes on excess:
  - Best fit is to resonance with $m \approx 750$ GeV and $\Gamma \approx 45$ GeV
  - Excess not evident in Run 1 data
    - but data sets are consistent within 2σ
- Limit on narrow Higgs-like resonance:



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Diphotons in Run 1

Phys. Rev. D 92, 032004 (2015)