Search for New Physics with the ATLAS Detector at $\sqrt{s}$ = 13 TeV

Haichen Wang
Lawrence Berkeley National Laboratory

For the ATLAS Collaboration

Particle Physics on the Verge of Another Discovery?

Aspen Winter Conference
January 12th 2016

Introduction

- After two years shut down, LHC has finally restarted, operating at a center of mass energy of 13 TeV.

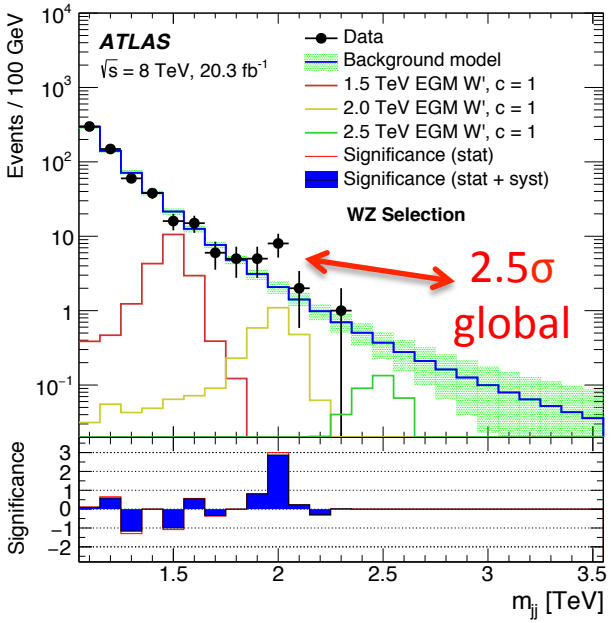
- The increase of center of mass energy from 8 TeV to 13 TeV has enabled a large number of new physics searches to surpass its sensitivity achieved in Run-1.

- I will report the ATLAS new physics search result based on a sample of ~3.2 – 3.6 fb^{-1} with good data quality taken in 2015.

Disclaimer:

- Searches beyond SUSY are covered.
- I will focus on signature, observation, and interpretation. I will not discuss more technical aspects, e.g., reconstruction and particle reconstruction, background estimation, etc..

Searches for diboson resonance



Run-1⇧

$X \rightarrow V\,V' \rightarrow J\,J$

ATLAS-CONF-2015-073

$X \rightarrow W\,V \rightarrow l\nu\,J$

ATLAS-CONF-2015-075

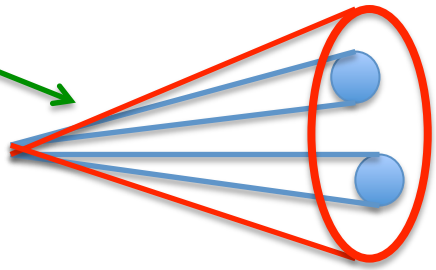
$X \rightarrow Z\,V \rightarrow ll\,J$

ATLAS-CONF-2015-071

$X \rightarrow Z\,V \rightarrow \nu\nu\,J$

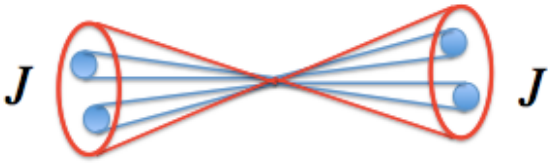
ATLAS-CONF-2015-068

Large R jet



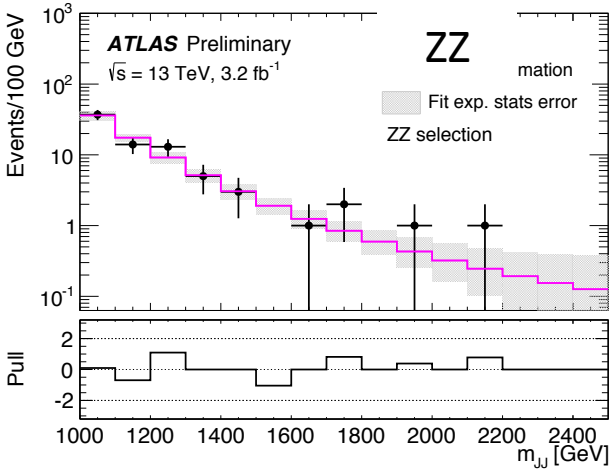
- Anti-kt 1.0 jet
- Trimming: removing pile-up and underlying events contribution.
- D_2: 2-prong nature
- Jet mass window

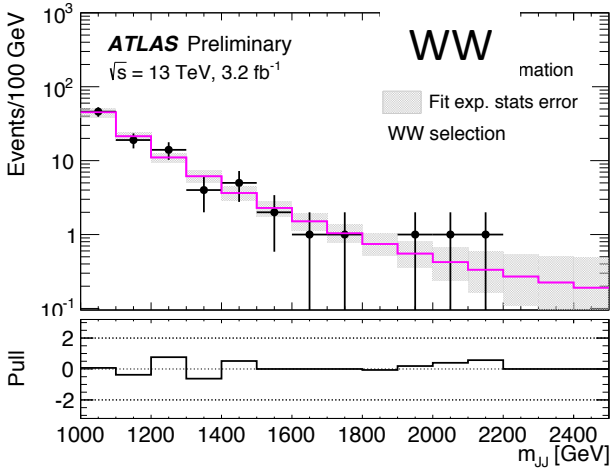
$X \rightarrow V\,V' \rightarrow J\,J$

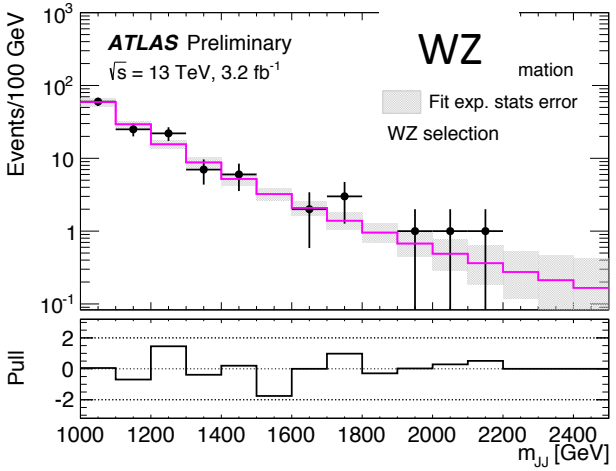


Main selection:

- Large R jet $p_T > 200$ GeV , $|\eta| < 2.0$
- Cut on number of tracks associated with the large R jet
- Leading large R jet $p_T > 450$ GeV
- Other topology cut to suppress QCD multijet.
- $m_{jet}^{W\text{-tag}} = 83.2 \pm 15$ GeV; $m_{jet}^{Z\text{-tag}} = 93.4 \pm 15$ GeV;

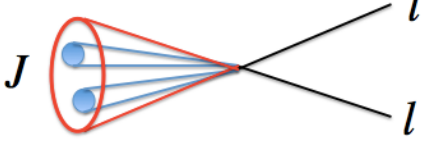


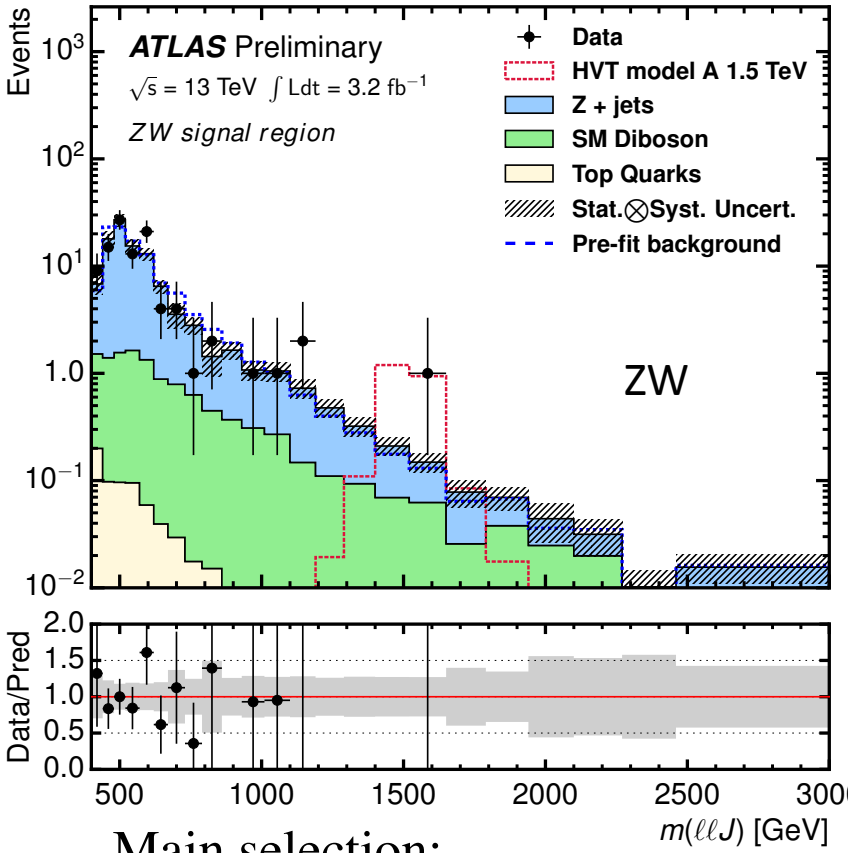


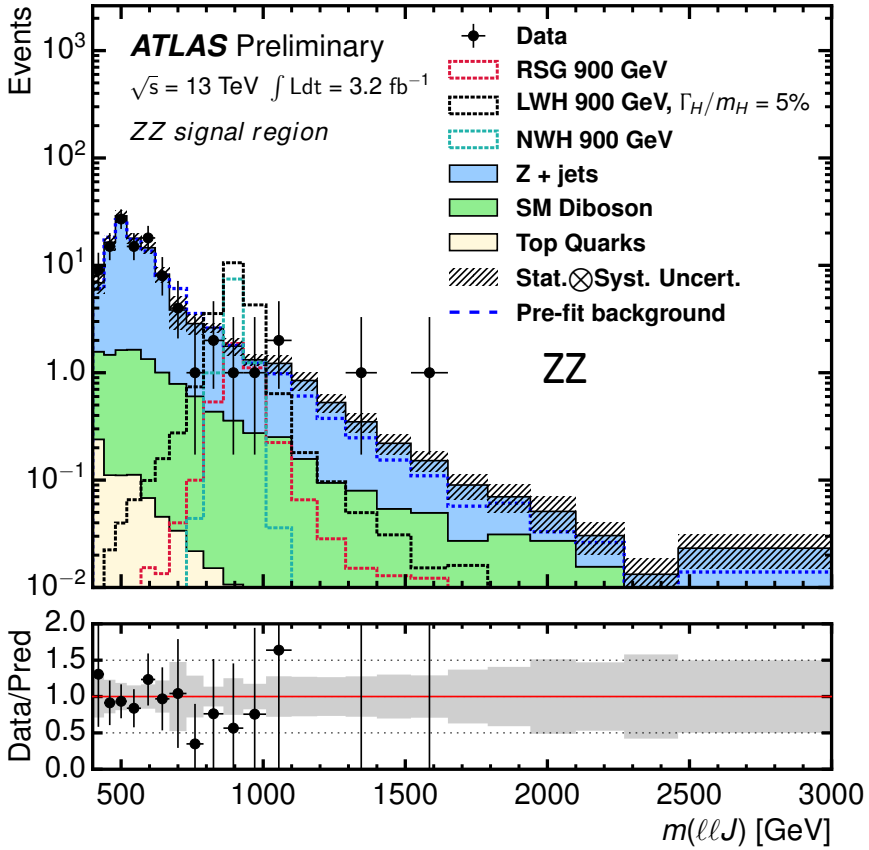


Background estimated by fitting the mass spectrum with an analytic function.

$X \rightarrow Z\,V \rightarrow ll\,J$





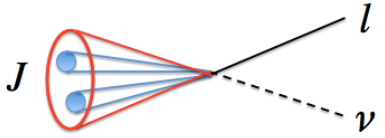


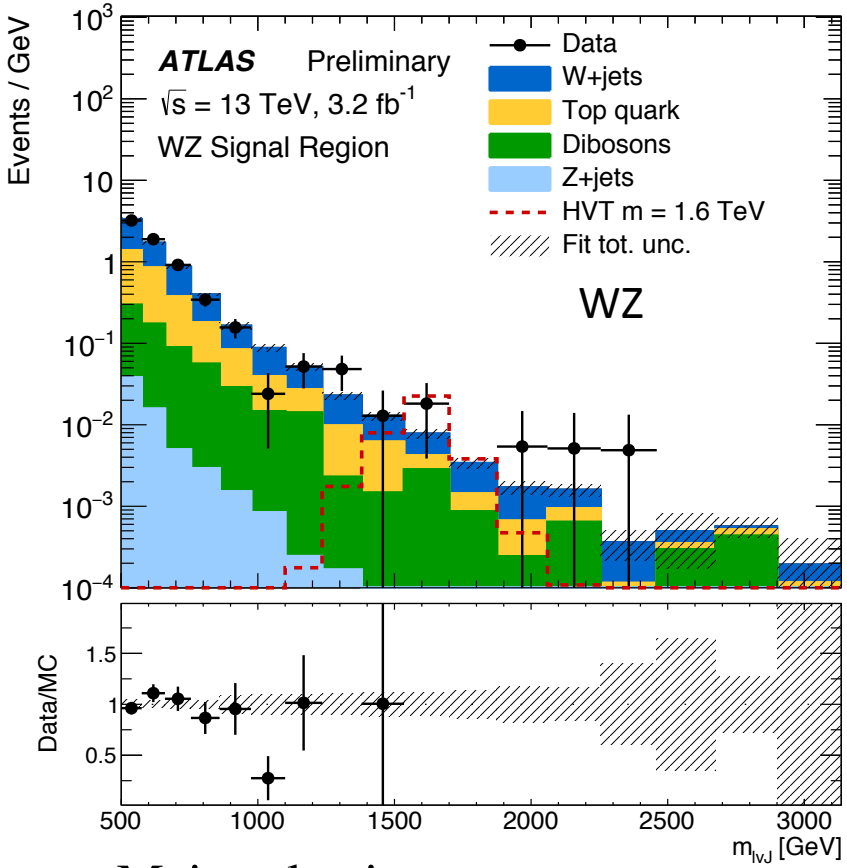
Main selection:

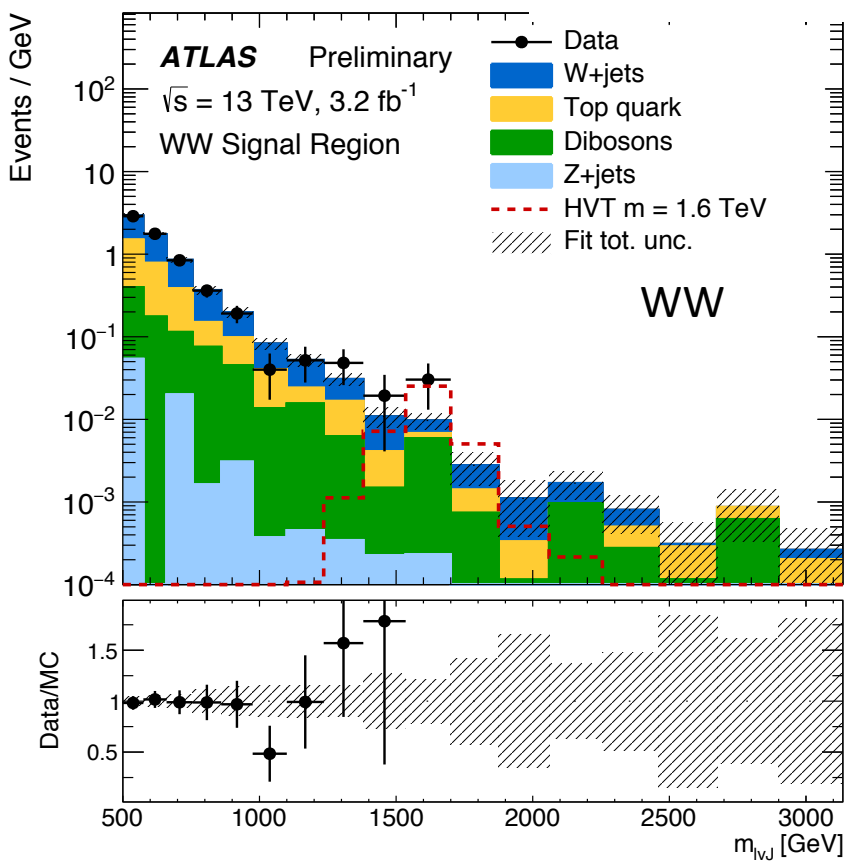
- Large R jet $p_T > 200$ GeV , $|\eta| < 2.0$
- $m_{jet}^{\text{W-tag}}$ 83.2 ± 15 GeV; $m_{jet}^{\text{Z-tag}}$ 93.4 ± 15 GeV;
- **$p_{T,ll}/m_{llJ} > 0.4$, $p_{T,J}/m_{llJ} > 0.4$**

Background estimated by control regions in the sidebands of large R jet mass.

$X \rightarrow W\,V \rightarrow l\nu\,J$





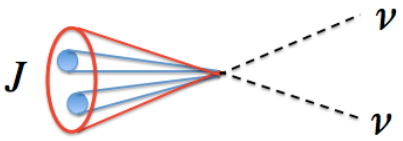


Main selection:

- Large R jet $p_T > 200$ GeV , $|\eta| < 2.0$
- $m_{jet}^{W\text{-tag}}$ 83.2 ± 15 GeV; $m_{jet}^{Z\text{-tag}}$ 93.4 ± 15 GeV;
- $p_{T,l} > 25$ GeV $E_T^{miss} > 100$ GeV, $p_{T(l,\nu)} > 200$ GeV,
- $p_{T(l,\nu)}/m_{(l,\nu,J)} > 0.4$, $p_{T(J)}/m_{(l,\nu,J)} > 0.4$

Background estimated by control regions in the sidebands of large R jet mass.

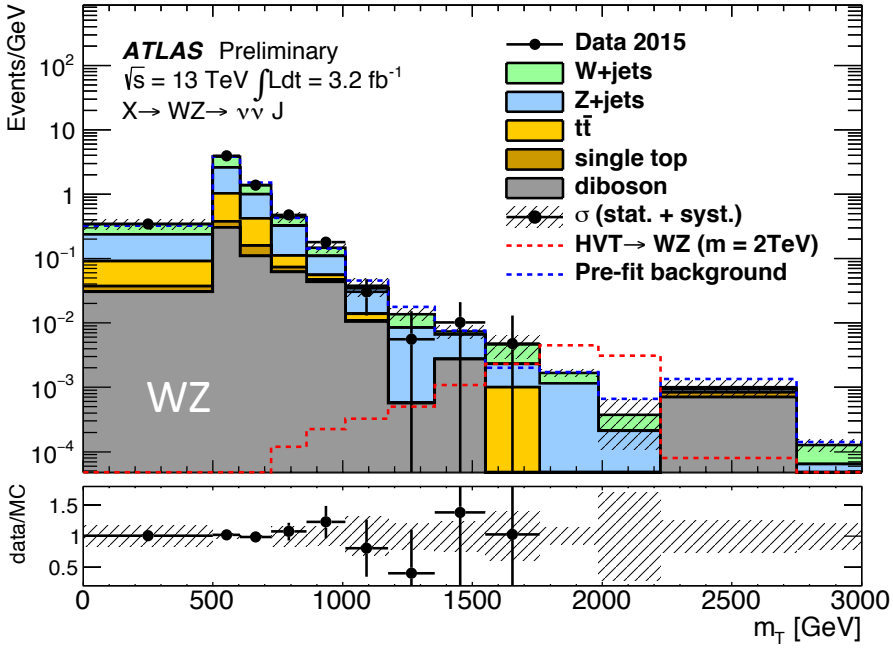
$X \rightarrow Z\,V \rightarrow \nu\nu\,J$

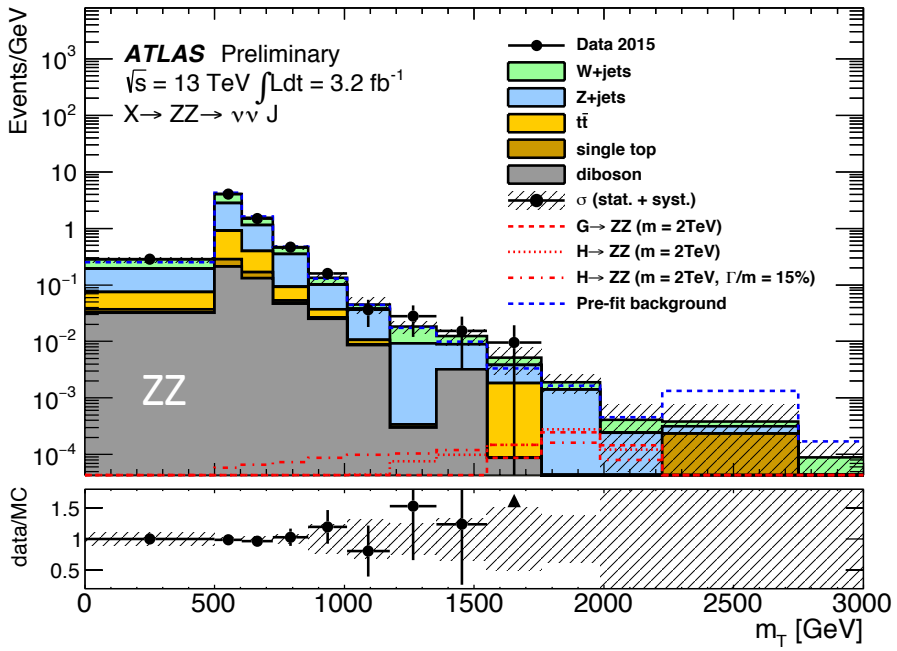


Main selection:

- Large R jet $p_T > 200$ GeV , $|\eta| < 2.0$, $m_{jet} > 50$ GeV
- $m_{jet}^{\text{W-tag}}$ 80.4 ± 15 GeV; $m_{jet}^{\text{Z-tag}}$ 91.2 ± 15 GeV;
- $E_T^{\text{miss}} > 250$ GeV

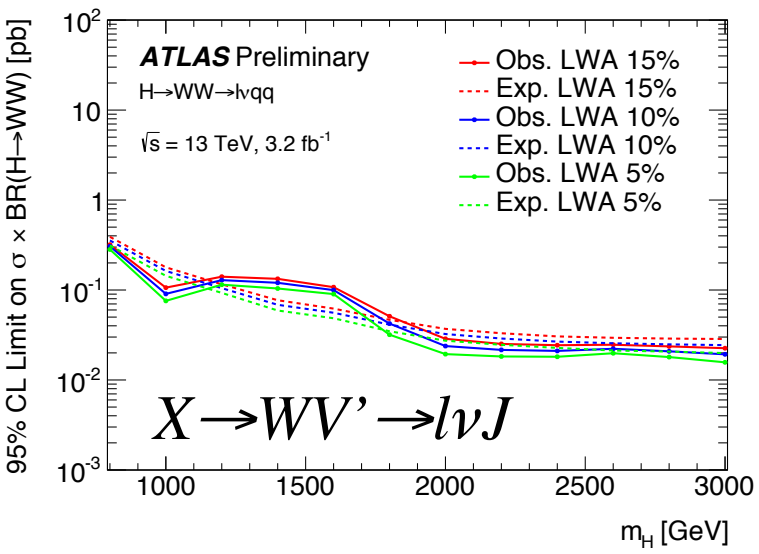
Background estimated by control regions in the sidebands of large R jet mass.

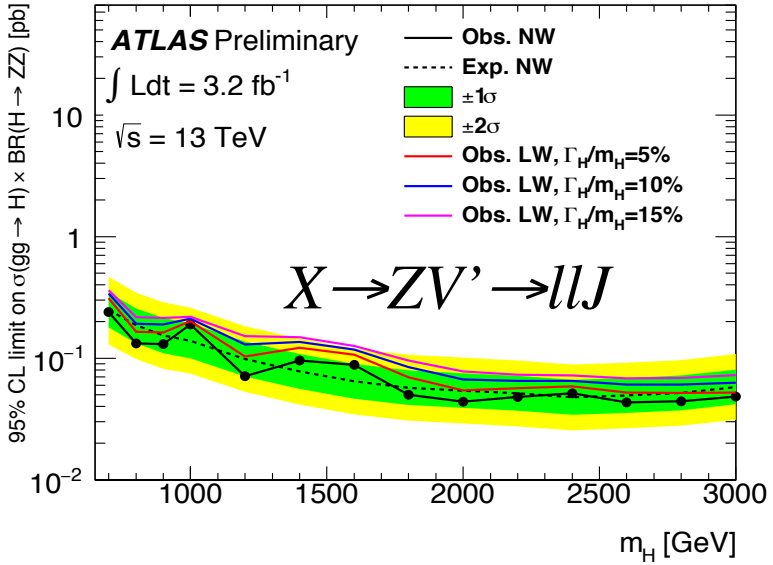




Interpretation of diboson searches

- No significant excess is seen in any of these final states.
- Two major benchmark models:
  - Randall-Sundrum (RS) graviton
    - excluded up to mass ~ 1.25 TeV by lνJ search.
  - Heavy Vector Triplet(HVT) model.
    - W' Z' excluded up to mass ~ 1.6 TeV by JJ and ννJ searches
- Limit on Heavy Higgs boson production cross section times and branching ratio for different resonance width assumptions.

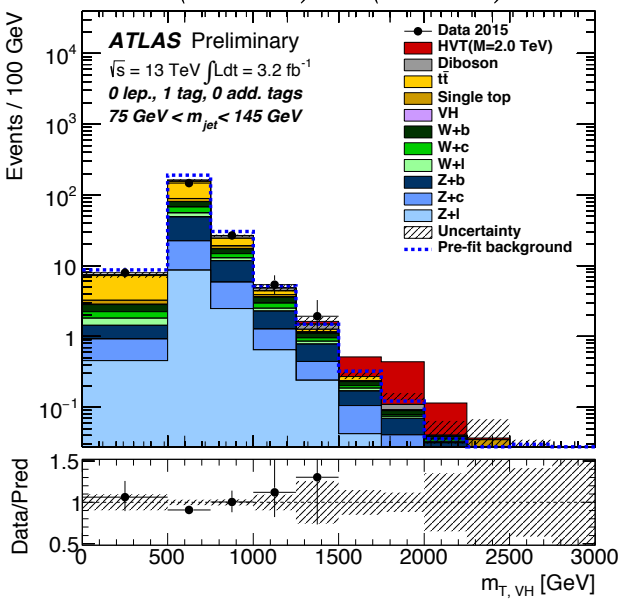




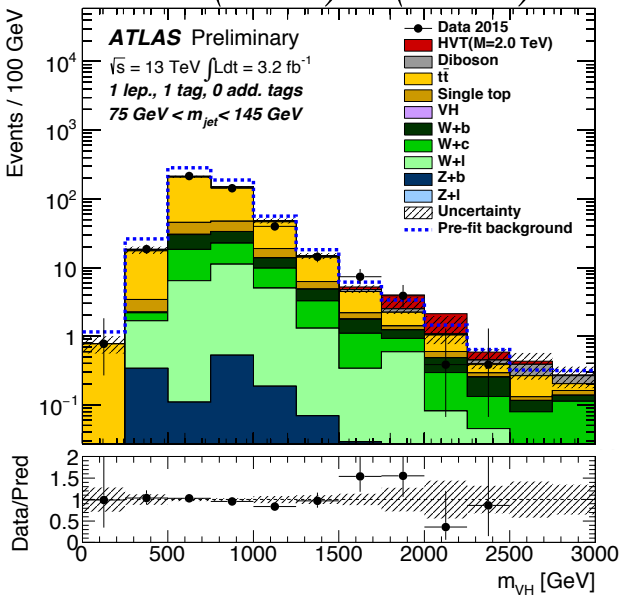
$X \rightarrow V(W \rightarrow l\nu, Z \rightarrow ll, Z \rightarrow \nu\nu)\ H(\rightarrow bb)$

- Large R jet
- 95 GeV < m_{jet} < 145 GeV,
- associated with b-tagged anti-kt 0.2 track jet

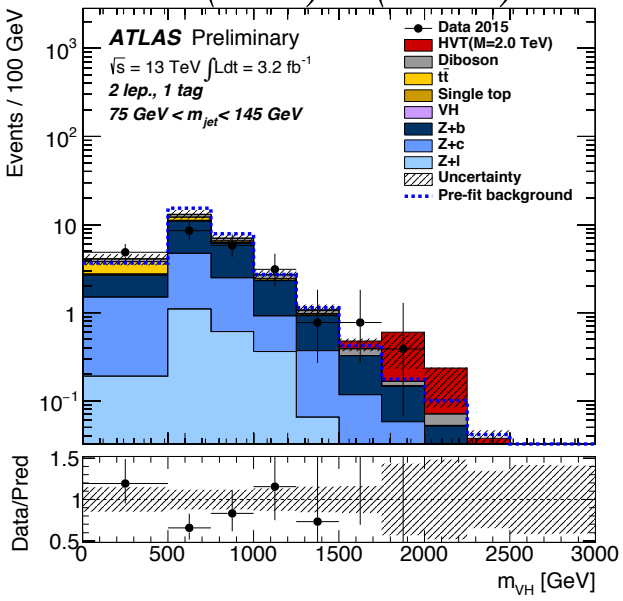
$Z(\rightarrow \nu\nu)\ H(\rightarrow bb)$



$W(\rightarrow l\nu)\ H(\rightarrow bb)$



$Z(\rightarrow ll)\ H(\rightarrow bb)$



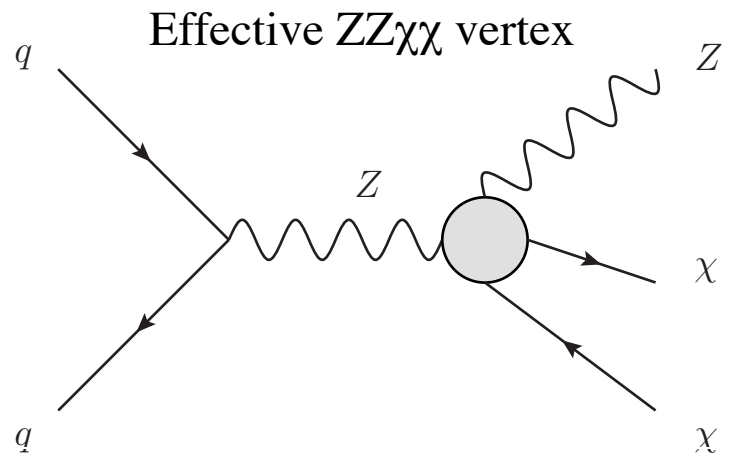
- Limit is set on the mass of Z', W' from HVT benchmark model(> 1.5 TeV for model A, > 2.0 TeV for model B), and the cross section of the CP odd scalar A from the 2-Higgs-Doublet model.

Search for particle dark matter candidate produced with a vector boson

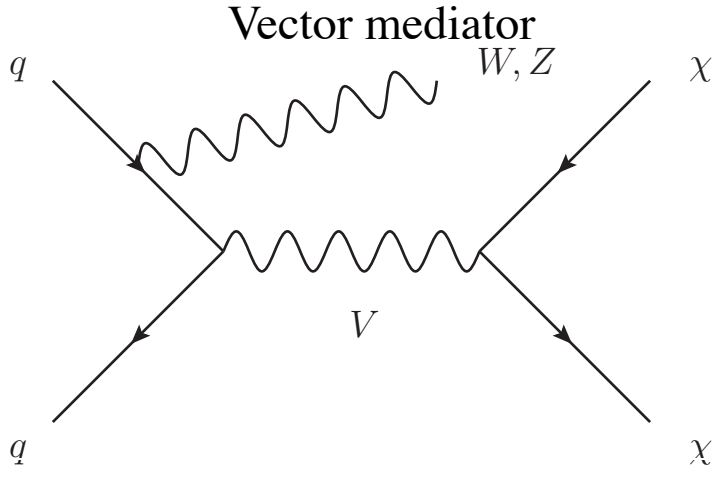
ATLAS-CONF-2015-080

Search for Dark Matter particle produced with a vector boson

Event topology is motivated by an effective field theory approach and a simplified model.



Carpenter, Nelson, Shimmin, Tait, Whiteson
Phys. Rev. D87.7 (2013) 074005



Buchmueller, Dolan, Malik, McCabe
JHEP 01 (2015) 037

A "large R" jet is used to tag the hadronic W/Z decay.

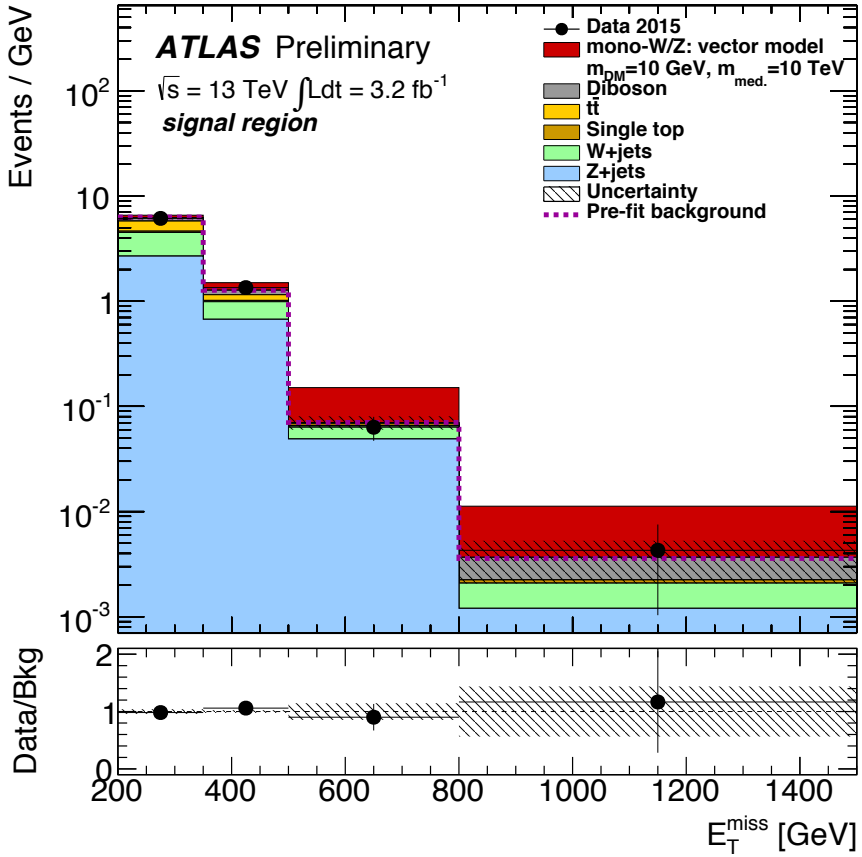
- one large R jet with $p_T > 200$ GeV, $|\eta|<2.0$

Dark matter particles escape detection, leading to large E_T^{miss}

- $E_T^{miss} > 200$ GeV.

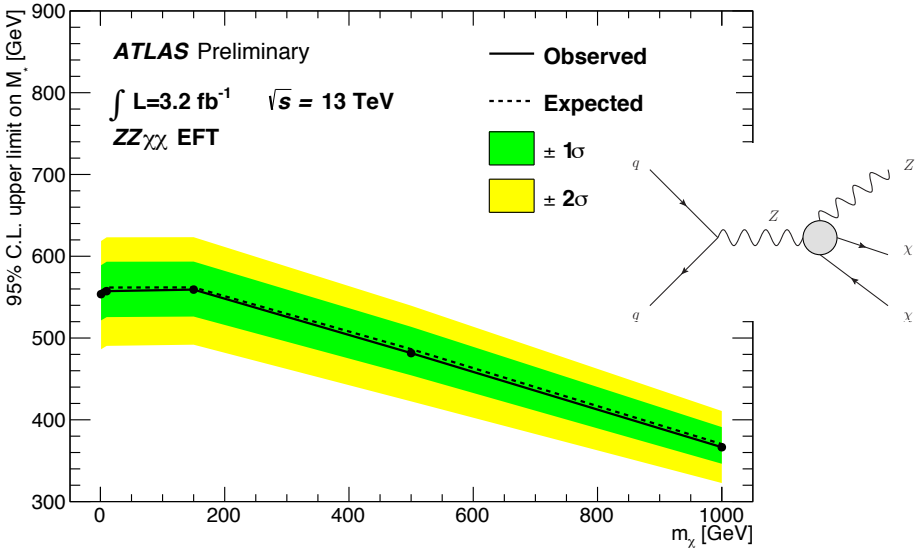
Search for excess in events with large E_T^{miss}.

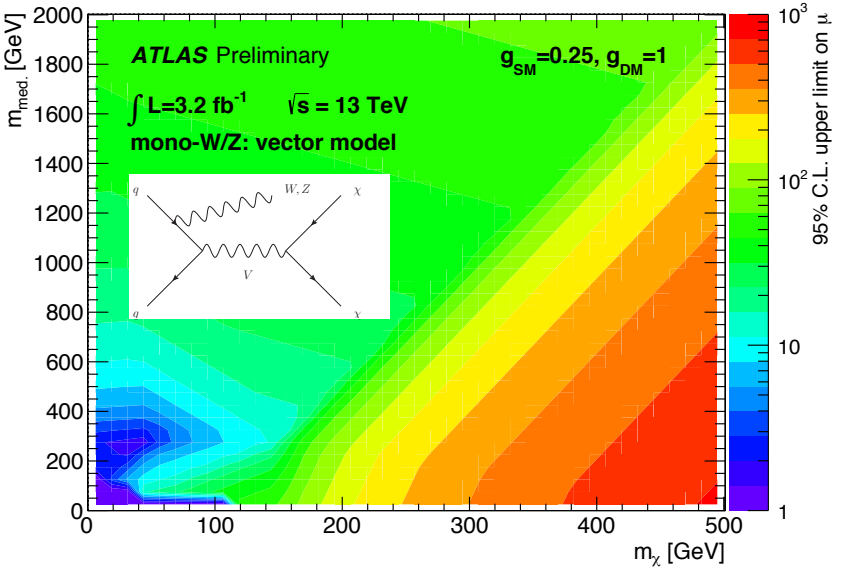
Search for Dark Matter particle produced with a vector boson



Limit on the vector mediator mass vs DM mass

Limit on the mass scale in the ZZχχ EFT model vs DM mass

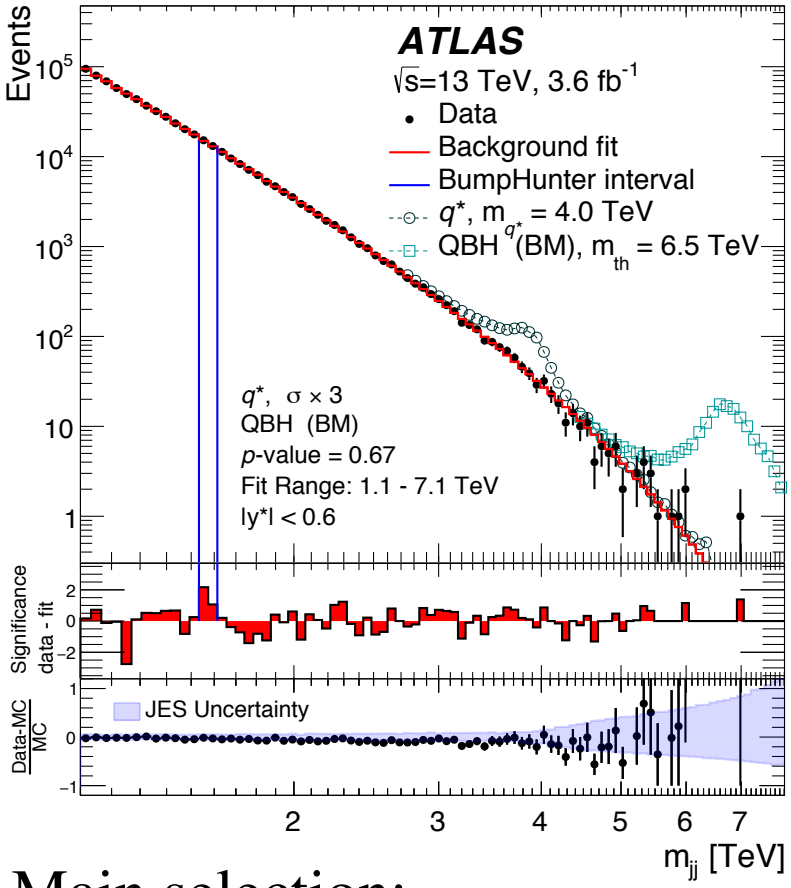


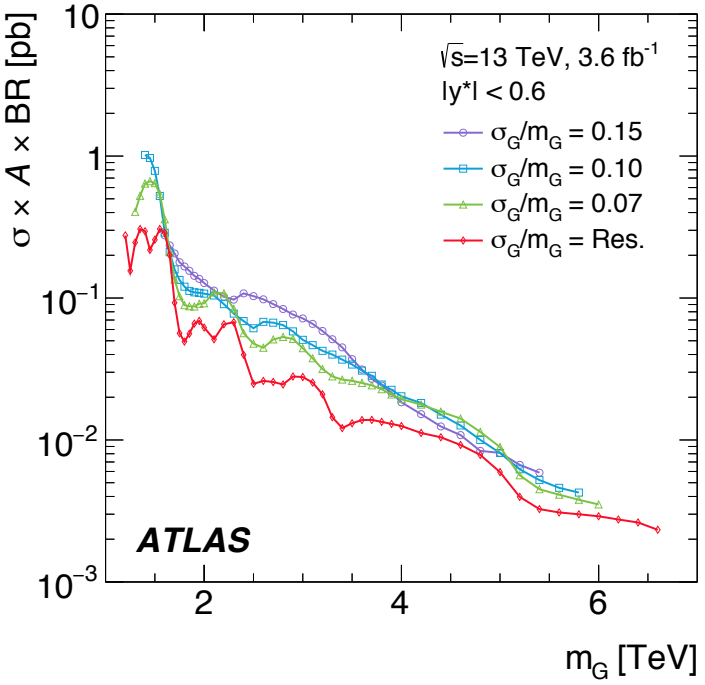


Searches for new physics at the highest energy with jet, lepton, photon and E_T^{miss}

Search for resonance in the dijet mass distribution

arXiv:1512.01530
Submitted to PLB





Main selection:

- Anti-kt 0.4 jet
- $p_{T1} > 440$ GeV, $p_{T2} > 50$ GeV
- $|y^*| = |y_1 - y_2|/2 < 0.6$

m_{jj} spectrum is fitted by an analytic function.

Search is carried out for signals with various width.

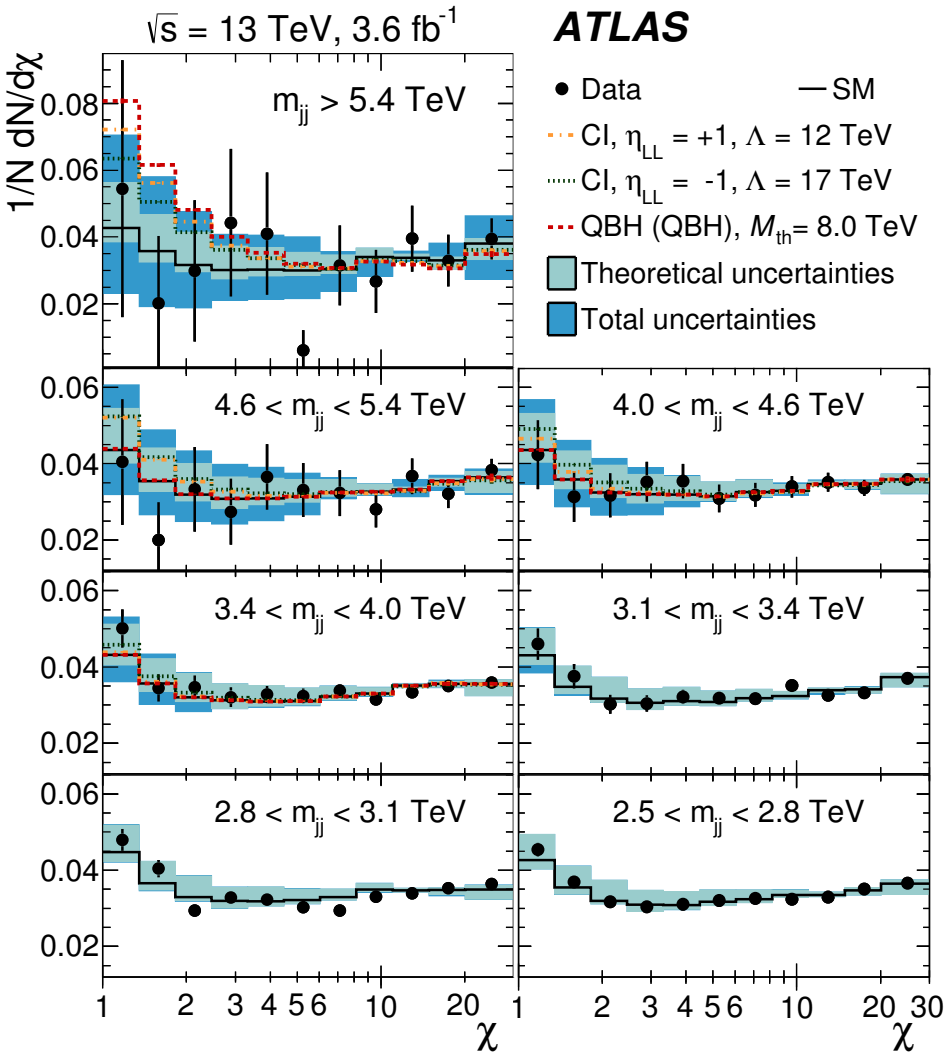
Quantum black hole (ADD, n=6) excluded up to 8.1 TeV

Quantum black hole (RS, n=1) excluded up to 5.2 TeV.

Excited quark excluded up to 5.2 TeV

Search for deviation in dijet angular distribution

arXiv:1512.01530
Submitted to PLB

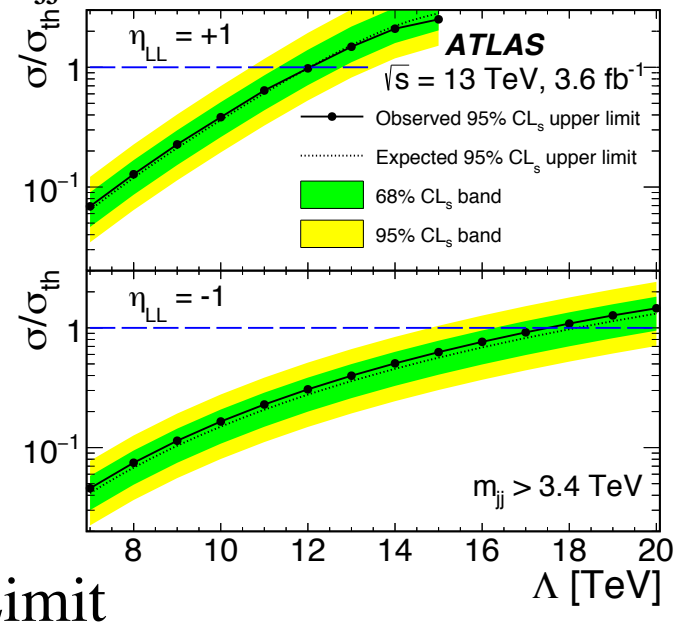


Signals from CI with left-chiral color singlet with constructive/destructive interference (η_{LL} = +/-1) shown.

Angular variable

$$\chi = e^{2|y^*|}$$

Sensitive to new physics such as Contact Interaction(CI) which doesn't give a resonance in m_{jj}



Limit

η_{LL} = +1, 12 TeV

η_{LL} = -1, 17.5 TeV

Search for excess in the multijet events

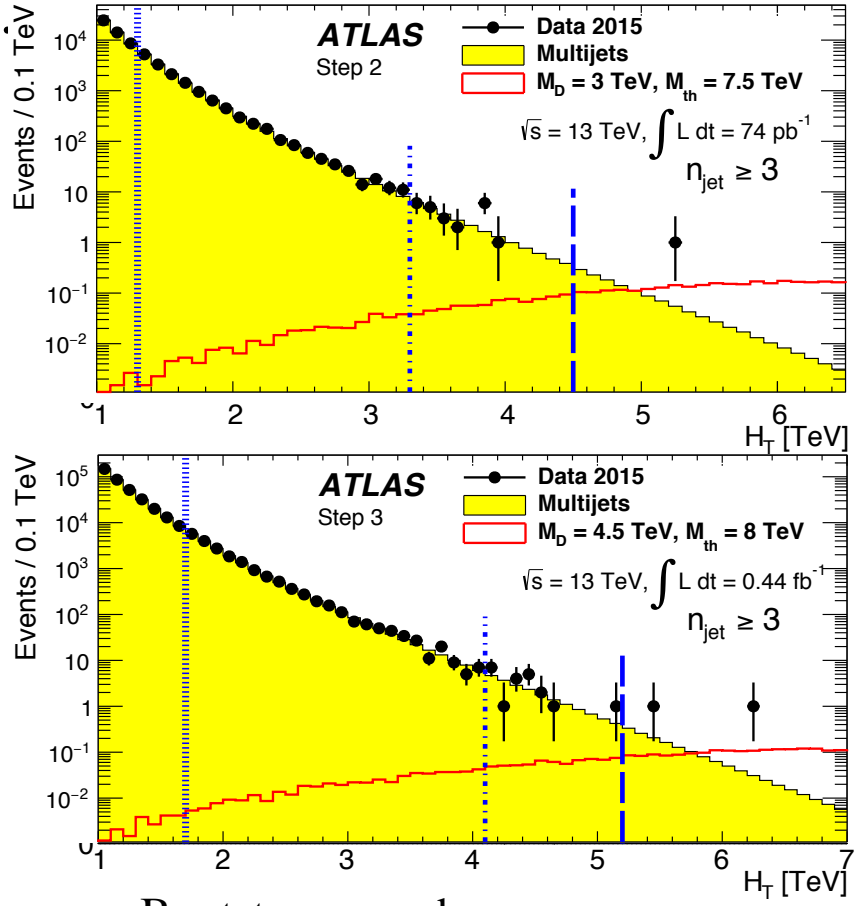
arXiv:1512.02586
Submitted to JHEP

Semi-classical black hole/string ball decay gives a large number of highly energetic particles.

Selection:

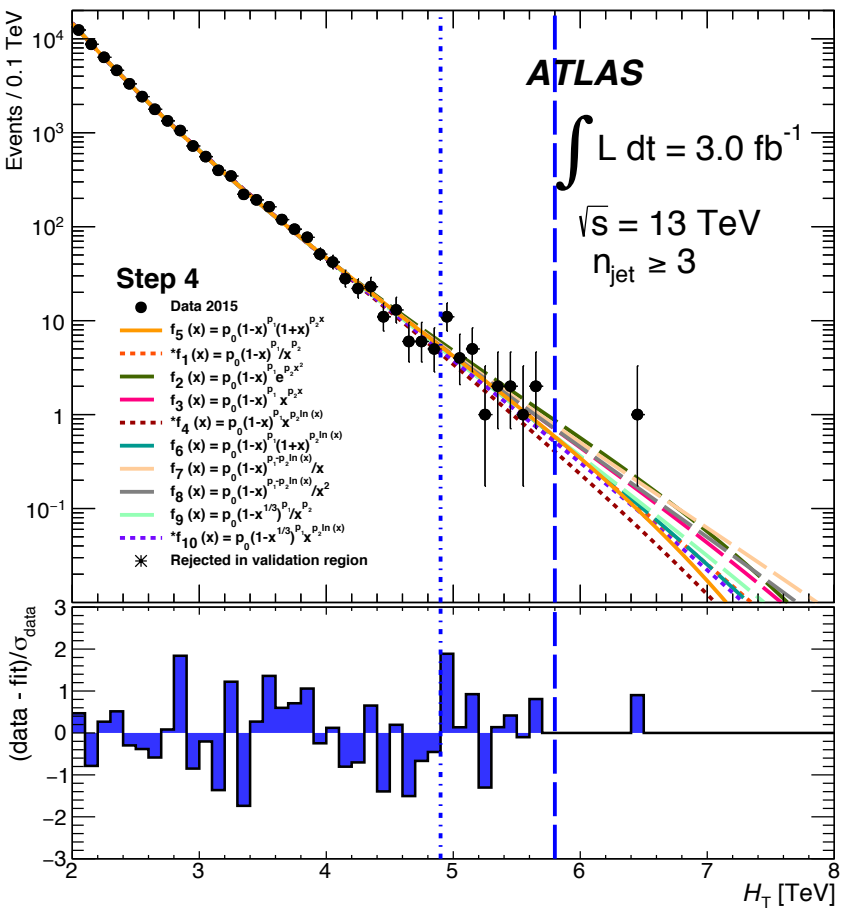
- All jets are high pT > 50 GeV
- |η|<2.8
- Leading jet pT > 200 GeV (trigger)
- Discriminating variable:
  - H_T scalar sum of jet pT.

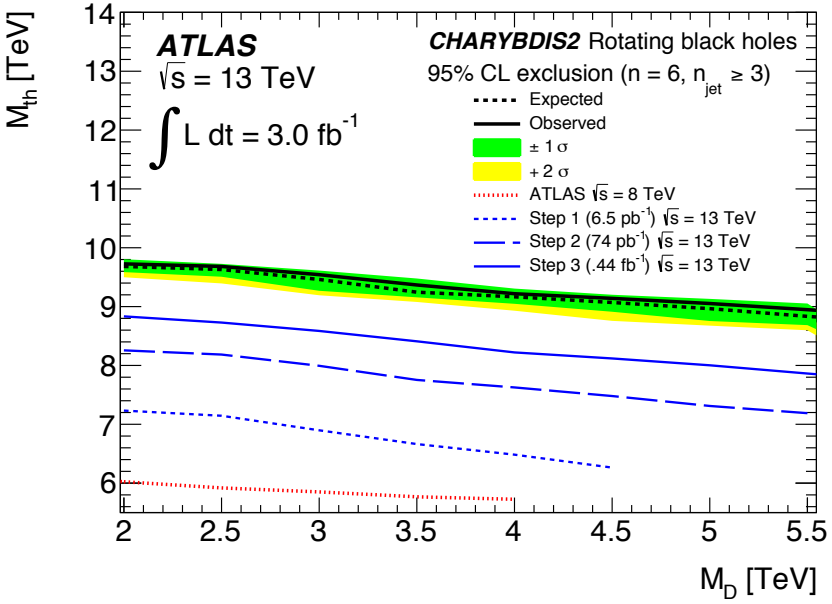
Analytic function fit data in a control region at low H_T, validation at an intermediate H_T region, signal region at high H_T.



Bootstrap search:
Small dataset with narrower CR
→
Large dataset with wider CR.

Search for excess in the multijet events





$n_{\text{jet}} \geq$	$H_{\text{T}} > H_{\text{T}}^{\text{min}}$ (TeV)	Expected limit (fb)	Observed limit (fb)
3	5.8	$1.63^{+0.70}_{-0.57}$	1.33
4	5.6	$1.77^{+0.70}_{-0.57}$	1.77
5	5.5	$1.56^{+0.73}_{-0.50}$	1.75
6	5.3	$1.52^{+0.69}_{-0.50}$	2.15
7	5.4	$1.02^{+0.36}_{-0.0}$	1.02
8	5.1	$1.01^{+0.29}_{-0.0}$	1.01

Data in the last step is used to set limit on black hole and string ball production.

A rotating black hole with n = 6, is excluded, for a mass up to 9.0 – 9.7 TeV, depending on M_D (Planck scale in a 4+n dimension world).

Search for excess in the photon+jet events

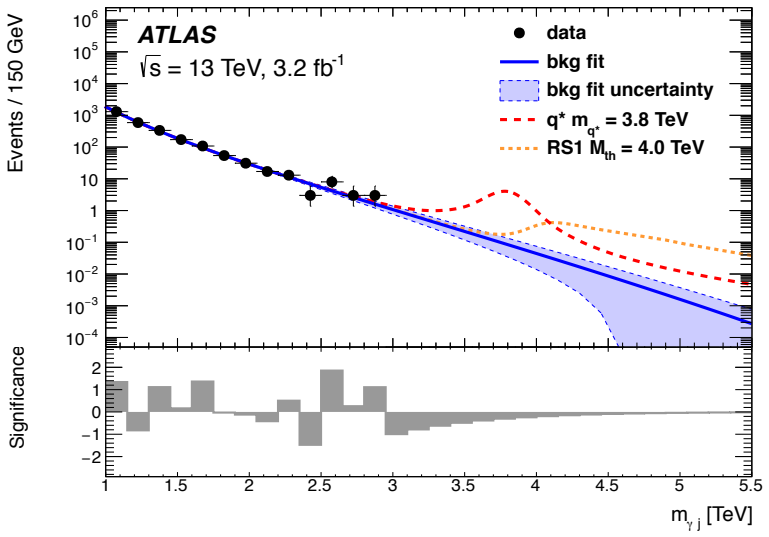
arxiv:1512.05910
Submitted to JHEP

Signature arises from models: Excited quark or quantum black hole (RS, ADD)

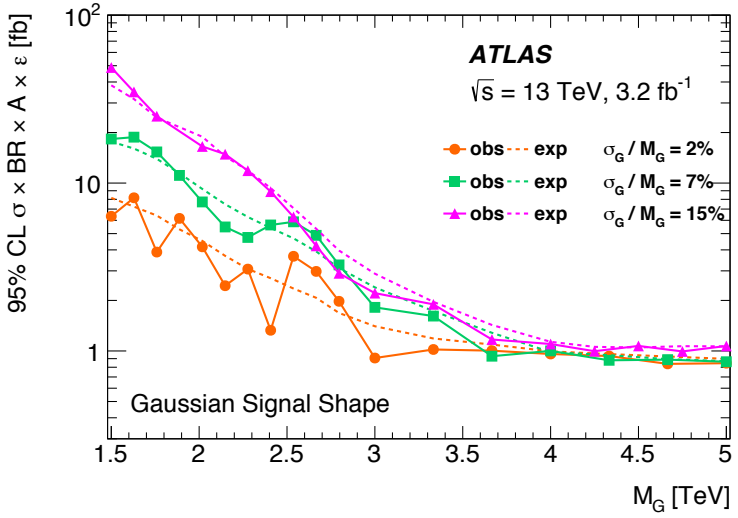
Selection:

- γ, jet $p_T > 150$ GeV
- Photon Isolation: $E_{Tcone20} < 2.45\ GeV + 0.022 * p_T$
- Within $\Delta R < 0.8$ of γ, no jet with $p_T > 30$ GeV.
- $|\eta| < 1.37$ (Barrel EM calorimeter)
- $|\Delta\eta_{\gamma jet}| < 1.6$

Limits are set on
excited quark mass > 4.4 TeV
QBH mass > 3.8 TeV (RS,n=1), 6.2 TeV (ADD, n=6).



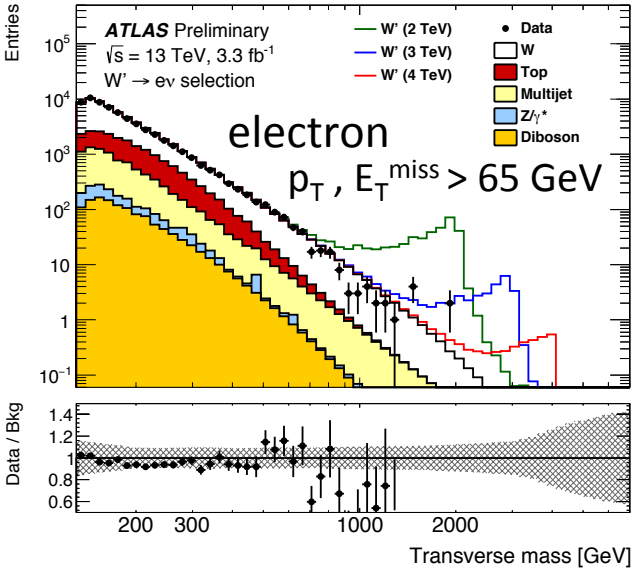
Limit on generic Gaussian resonance

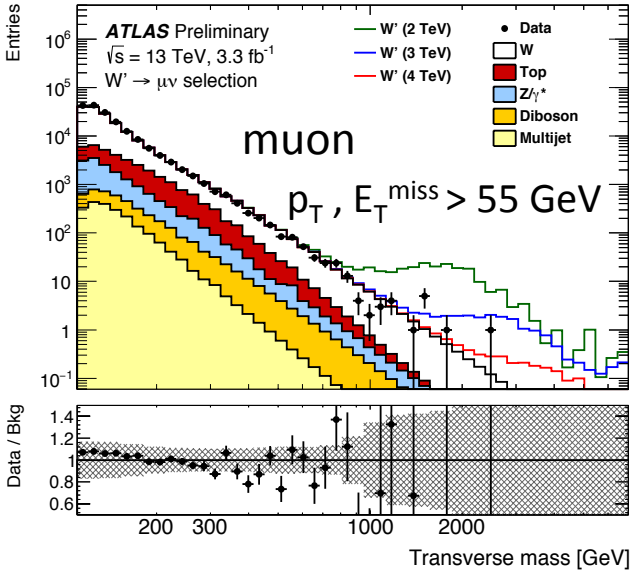


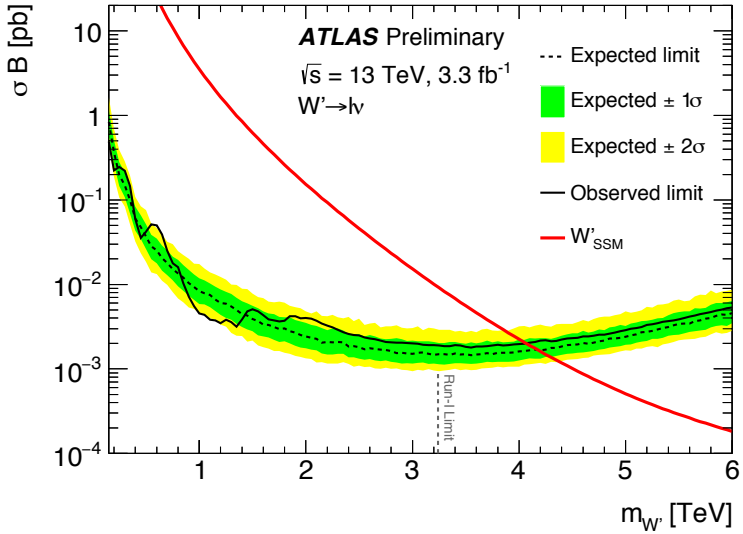
Search for lepton+E_T^{miss} resonance

ATLAS-CONF-2015-063

Events with a highly energetic lepton(e,μ) and large missing transverse energy(E_T^{miss}) can come from a high mass W' decay.





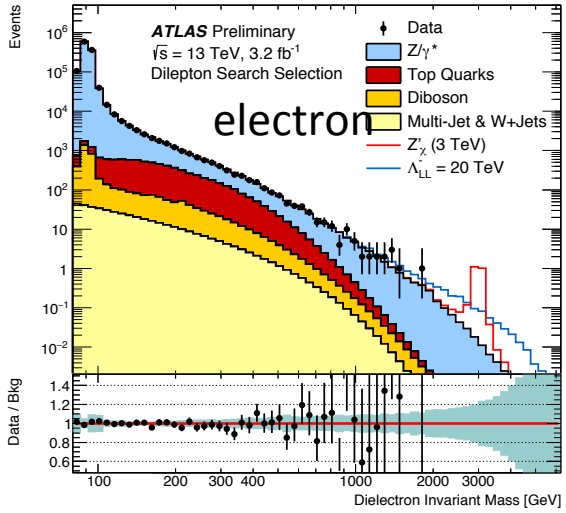


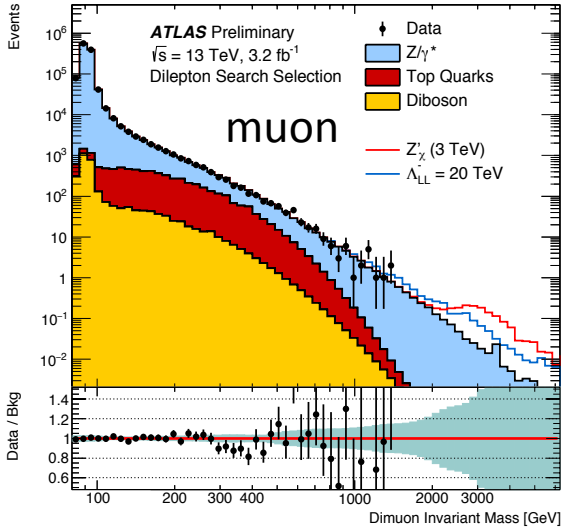
- Limit set on σBr for W'
- A Sequential Standard Model(SSM) W' is excluded up to 4.18 TeV.

Search for same flavor dilepton excess

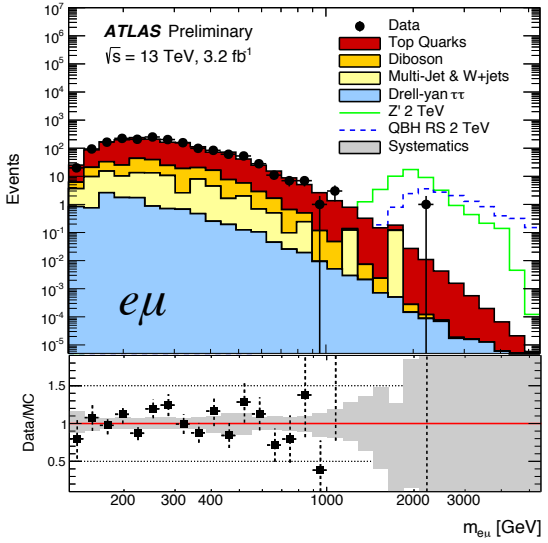
ATLAS-CONF-2015-070

Dilepton resonance: various models of Z'
Non-resonant effect: contact interaction

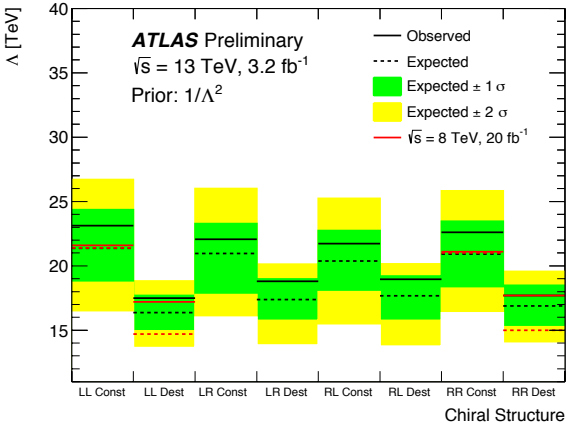




Lepton flavor violating SSM Z'
QBH $\rightarrow e\mu$



A SSM Z' is excluded up to 3.4 TeV (3.0 TeV) for the lepton flavor conserving (violating) SSM Z'.



Limit on the scale of *qqll* contact interaction: 16.4 TeV – 23.1 TeV

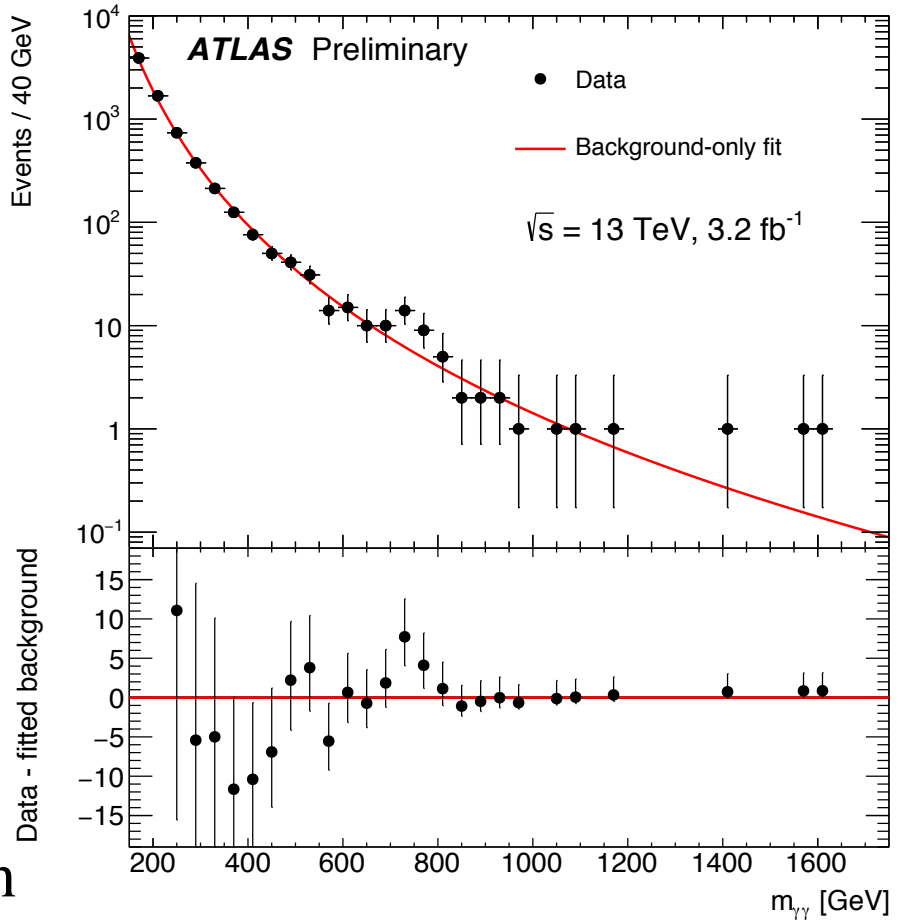
Search for diphoton resonance from a new scalar decay.

Selection:

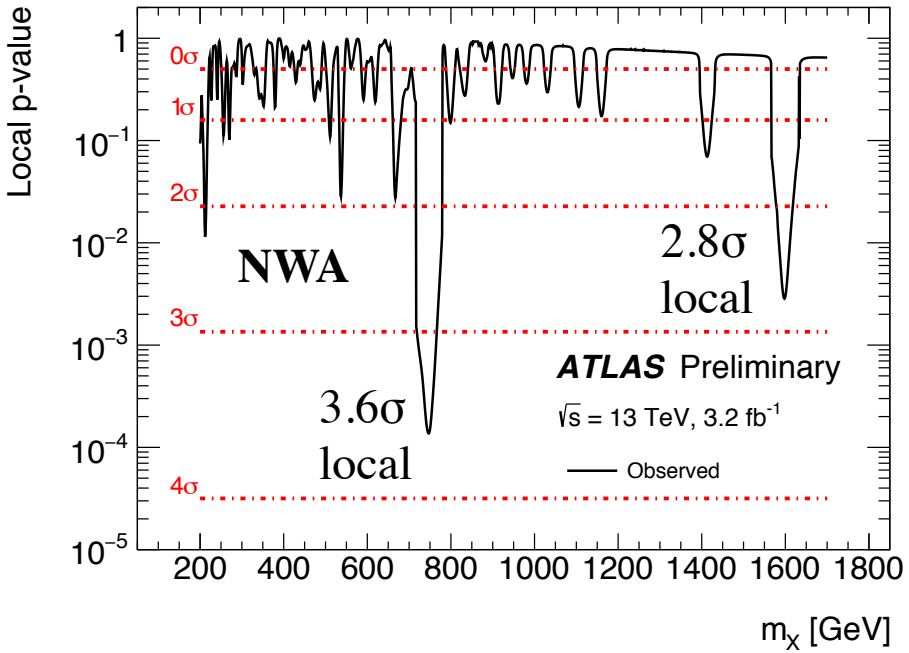
- Two photons with
  $E_{T,1}/m_{\gamma\gamma} > 0.4$
  $E_{T,2}/m_{\gamma\gamma} > 0.3$
  $|\eta|<1.37$ or $1.56 < |\eta|< 2.37$
  $E_T^{iso} < 0.022*E_T+2.45$ GeV
  $P_T^{iso} < 0.05*E_T$

Background is estimated by fitting the $m_{\gamma\gamma}$ spectrum with a signal plus background model.

Both signal with a Narrow Width Approximation(NWA) and signal with a large width are considered.



Search for diphoton resonance

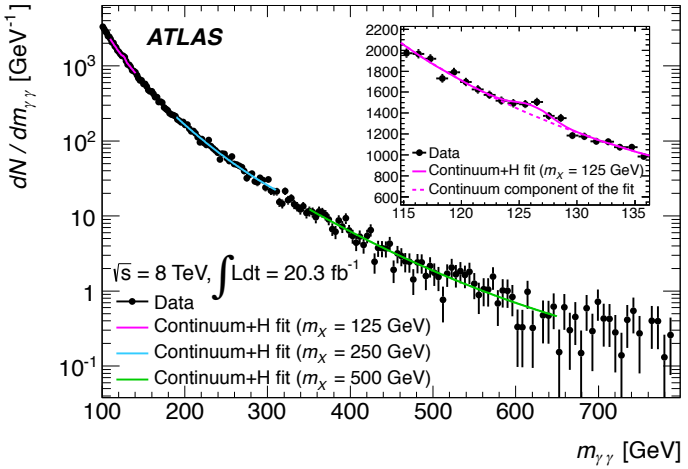


Large excesses seen at 750 GeV and 1.6 TeV.

Excess at 750 GeV		
	Local	Global
NWA	3.6σ	2.0σ
Γ ~ 45 GeV	3.9σ	2.3σ

- Property of events in the excess region is found to be consistent with that outside the region.

- Run-2 excess is compatible with Run-1 observation at 1.4 σ level for the Γ~45 TeV interpretation, 2.2 σ for the NWA.



Summary

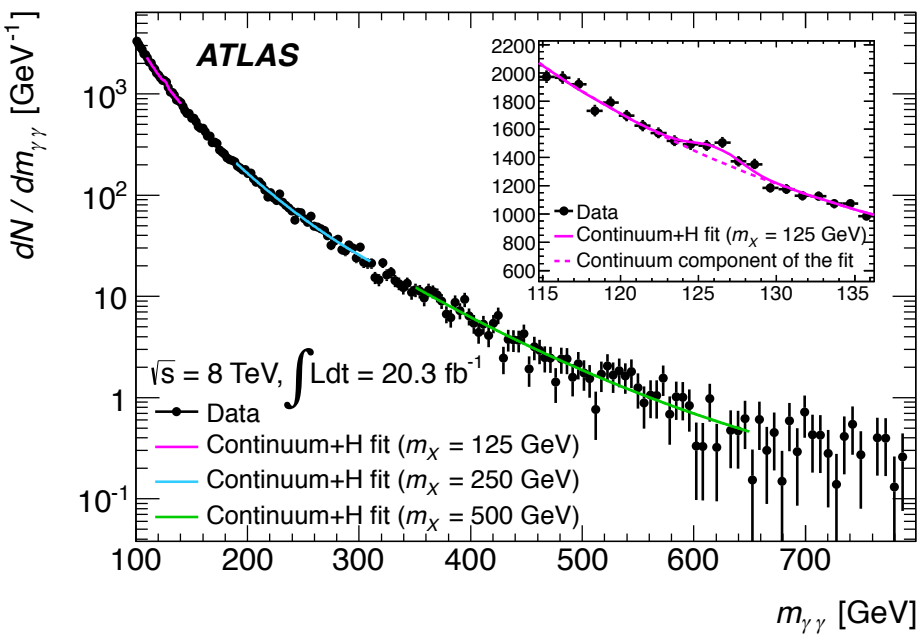
- A large number of searches for new physics have been carried out with the first 3.2 – 3.6 fb^{-1} of 13 TeV data taken in 2015.

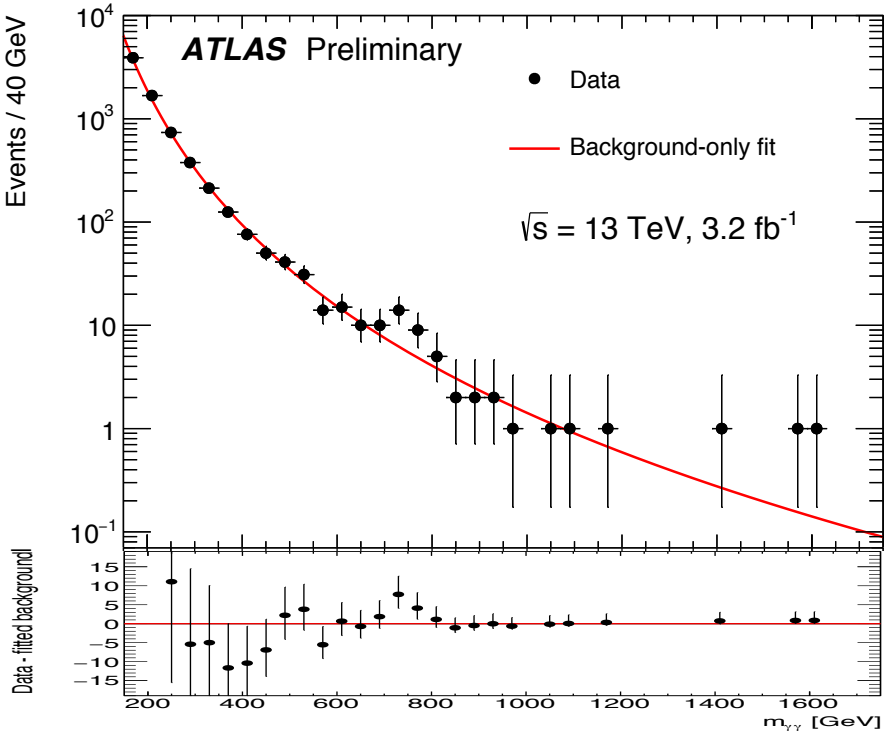
- Most searches saw no significant deviation from the background expectation. Constraints on new physics are stronger than the Run-1 results. The nature of the modest diphoton excess will soon be settled with more data.

- More results based on 2015 data will be released in March.

- Looking forward to an exciting 2016 run!

Search for diphoton resonance





- For a gluon initiated production, the parton luminosity increases by a factor of 4.7 from 8 TeV to 13 TeV.
- The current observation is consistent with Run-1 observation at 2.2σ and 1.4σ level for the NWA and Γ~45 GeV hypotheses, respectively.