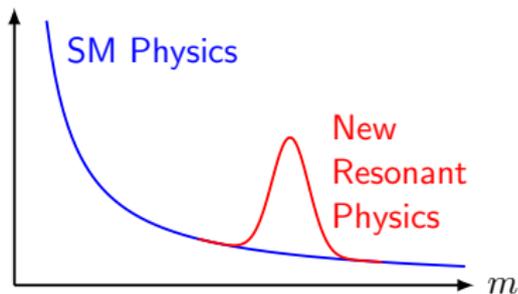
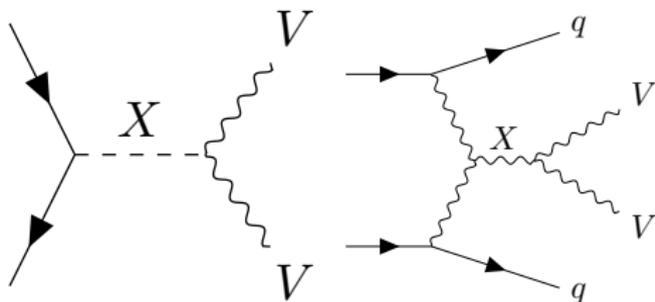


ATLAS Searches for VV Resonances

Robert Les
on behalf of the ATLAS Collaboration

Phenomenology 2019

- We know Standard Model of Particle Physics has short-comings
 - Dark Matter, Hierarchy Problem



- Various new physics models predict new particles decaying to pairs of $V = W/Z$
 - Extended Gauge/Higgs Sectors, Low-Scale Quantum Gravity
- Can appear as resonant detector signature in invariant mass of the bosons

Leptonic decays

- Low BR, low backgrounds

Hadronic decays

- High BR, high backgrounds

	Z	W
$ll/l\nu/\nu\nu, l = e, \mu$	27.3%	21.6%
$\tau\tau/\tau\nu$	3.4%	10.8%
qq	69.2%	67.6%

Each final state:

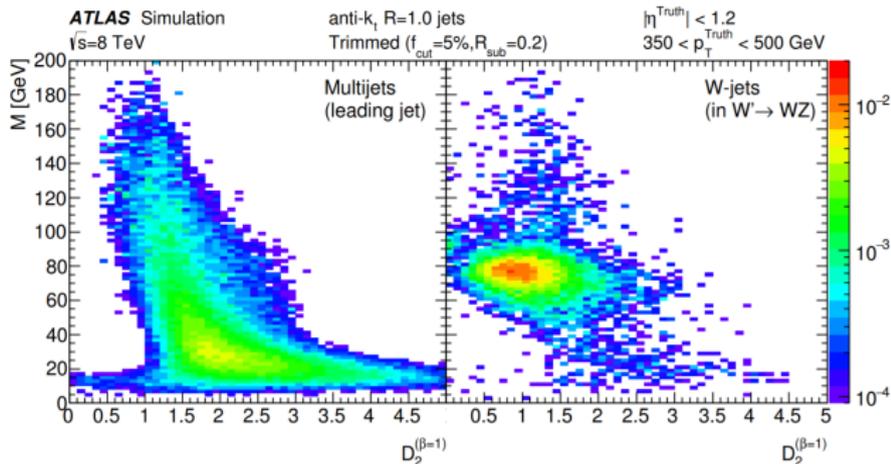
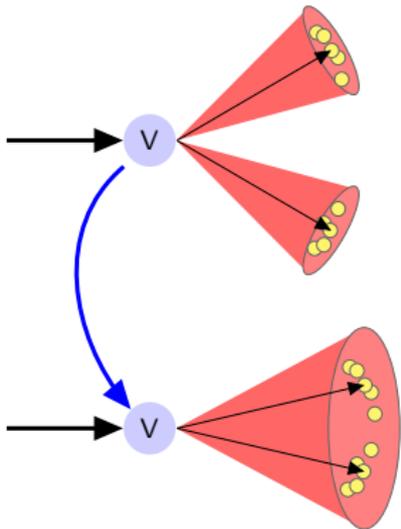
- Requires a dedicated search
 - Different background and experimental techniques
- Has different sensitivity to model parameters
 - Ex: hadronic best at high mass

Production modes investigated

- Gluon-gluon-fusion
- Quark-antiquark annihilation
- Vector-boson-fusion
 - Two additional forward jets

In this talk I will summarize the existing ATLAS VV results which use hadronic decays

For high- p_T boson
reconstruct hadronic
decays as large-R jets



To reduce backgrounds with large-R jets can design a V -tagger based on:

- Mass of the large-R jet
- Peak at V mass
- $D_2^{\beta=1}$ sub-structure variable
- Ratio of energy correlation functions

$VV \rightarrow lvqq/\ell\ell qq + \nu\nu qq$ with 36fb^{-1}

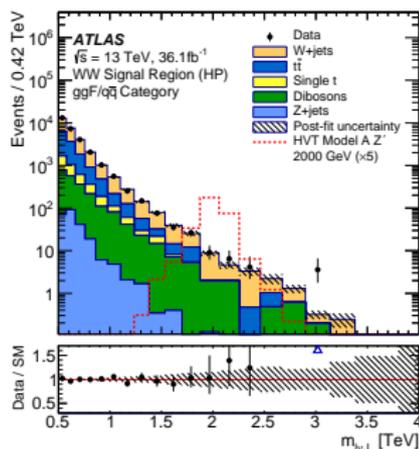
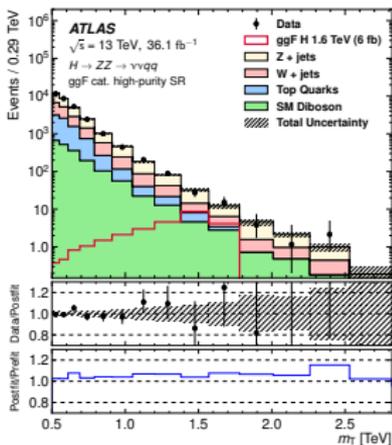
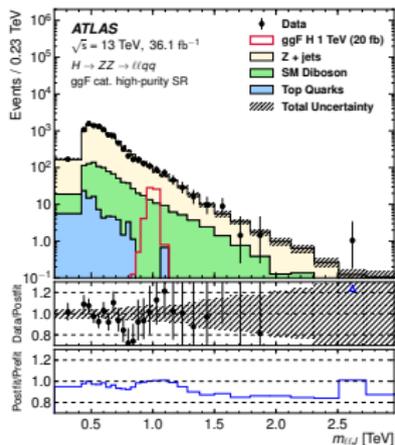
Two searches for:

JHEP 03 (2018) 042 + JHEP 03 (2018) 009

- $WV \rightarrow lvqq$
- $ZV \rightarrow \ell\ell qq + \nu\nu qq$
- Leptons for trigger and background rejection
- Hadrons for higher BR

Use dedicated control regions to measure background

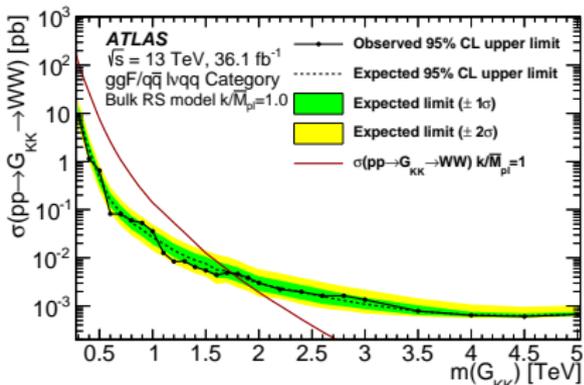
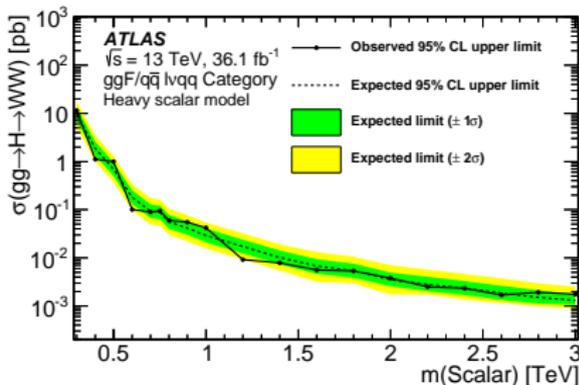
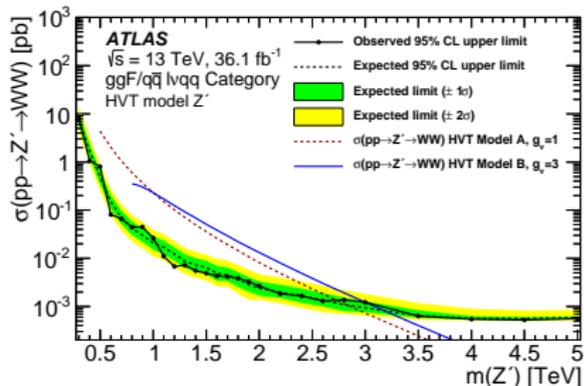
- Mass side-bands: V +jets
- b -tagged regions: $t\bar{t}$



No significant excesses were found

Analysis set limits in 3 models:

- Spin-0: Heavy Higgs
- Spin-1: Heavy Vector Triplet
- Spin-2: RS Graviton

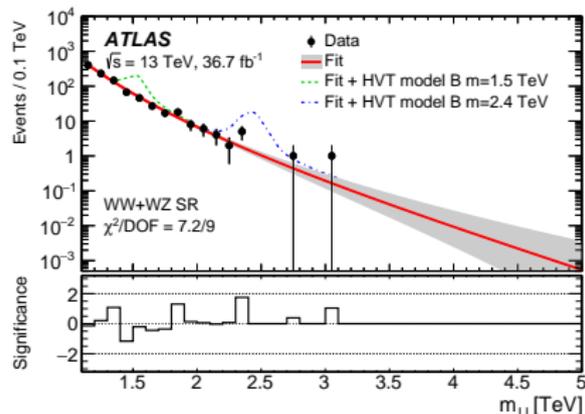
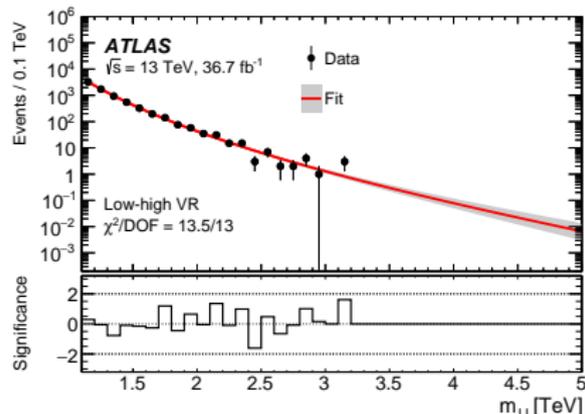
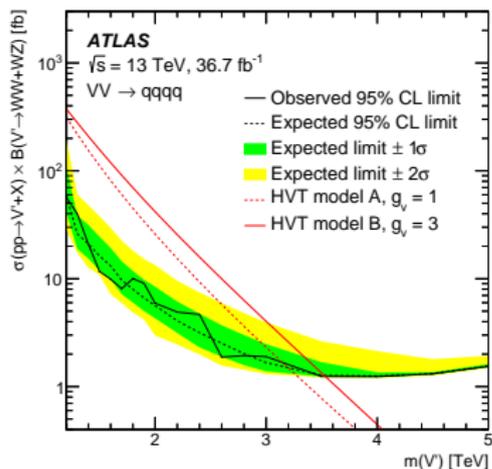


Data driven search looking for two large-R V -tagged jets

- Fit to “dijet” function

$$\frac{dn}{dx} = p_1(1-x)p_2 - \xi p_3 x^{-p_4}$$

- Validated in sideband region

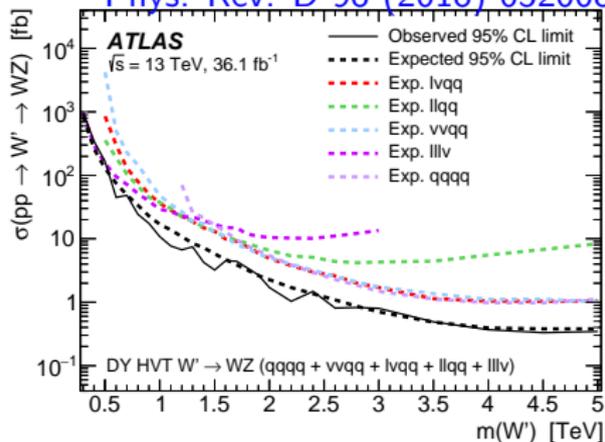


Combination of VV results with 36fb^{-1}

Phys. Rev. D 98 (2018) 052008

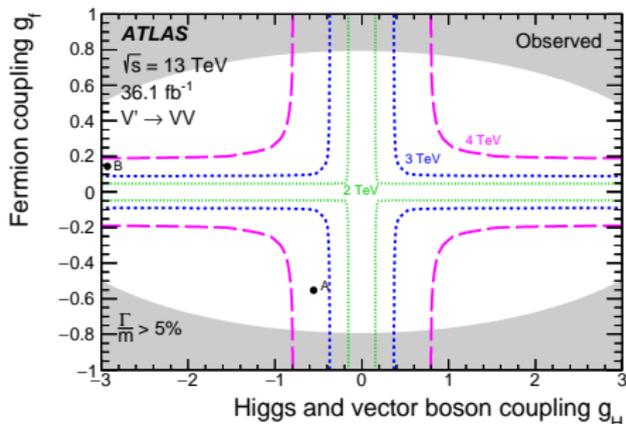
ATLAS has also done a combination result of the VV resonance searches

- Provides the best limits
 - Leptonic contribute at low-mass
 - Hadronic contribute at high-mass
- Result also combines with VH and dilepton resonances

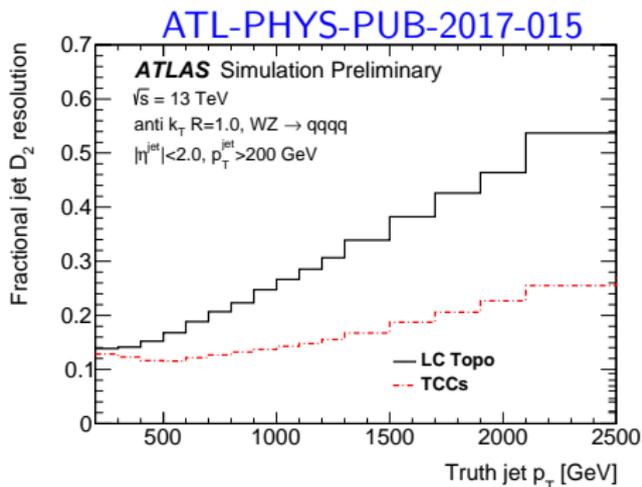
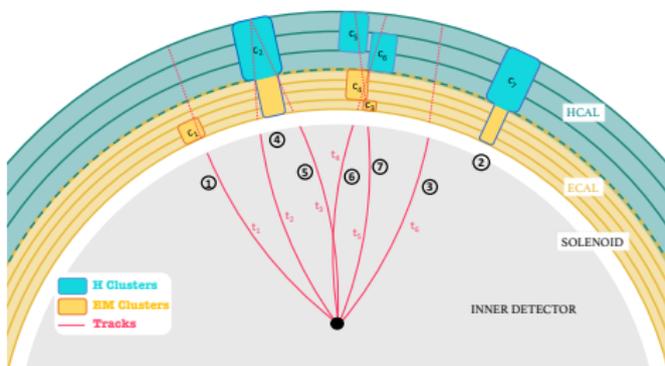


For Heavy Vector Triplet model also probe limits as a function of couplings

- Toy model with couplings as free-parameters
- First limits in this format by ATLAS



Future Experimental Improvements: Track-CaloClusters



Track-CaloClusters (TCC) is a new particle-flow type algorithm

- Use tracks for better angular resolution, calorimeter for better energy resolution
- Significant improvement in substructure resolution
 - Better V -tagging in future

VV resonances are a strong part of the ATLAS exotic program

- Six publications in various final states
- Only discussed the fully-hadronic and semi-leptonic final states

Within last year many new ideas have been investigated

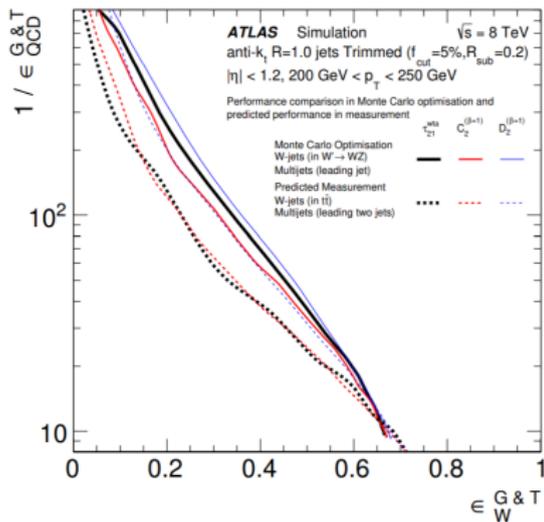
- Combination of results:
 - Exploits complimentary of analyses to provide strongest limits
- Experimental improvements
 - TCC jets have been found to provide large improvements

BACKUP

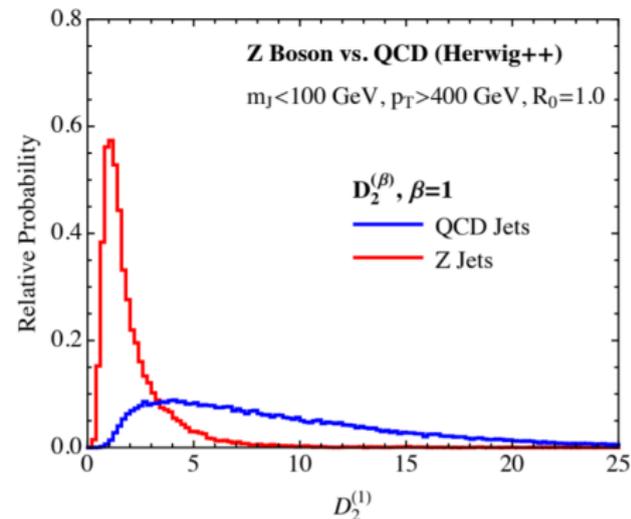
$$D_2^\beta = \frac{e_3^\beta}{(e_2^\beta)^3}$$

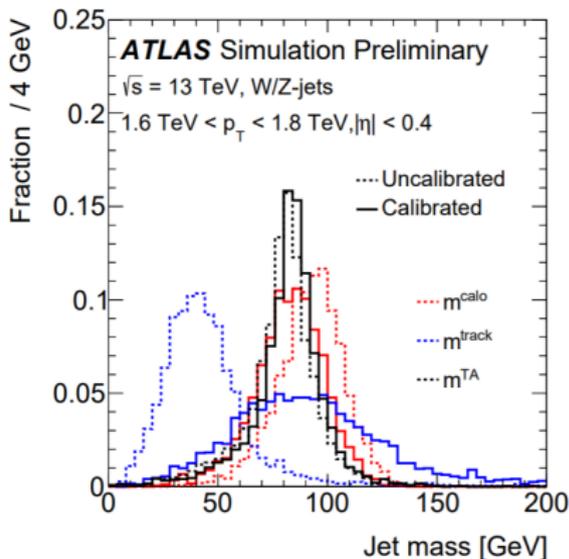
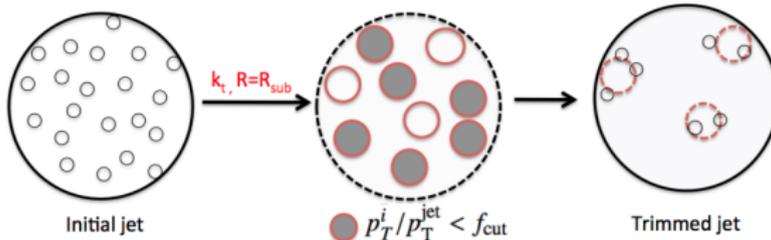
$$e_2^\beta = \frac{1}{p_{TJ}^2} \sum_{1 \leq i \leq j \leq n_J} p_{Ti} p_{Tj} R_{ij}^\beta$$

$$e_3^\beta = \frac{1}{p_{TJ}^3} \sum_{1 \leq i \leq j \leq k \leq n_J} p_{Ti} p_{Tj} p_{Tk} R_{ij}^\beta R_{ik}^\beta R_{jk}^\beta$$



$D_2^{\beta=1}$ found to have best background separation in ATLAS in comparison to similar sub-structure variables





Trimming (above):

Remove pile-up contamination by re-clustering with k_T algorithm and remove those failing $\frac{p_T^i}{p_T} < f$

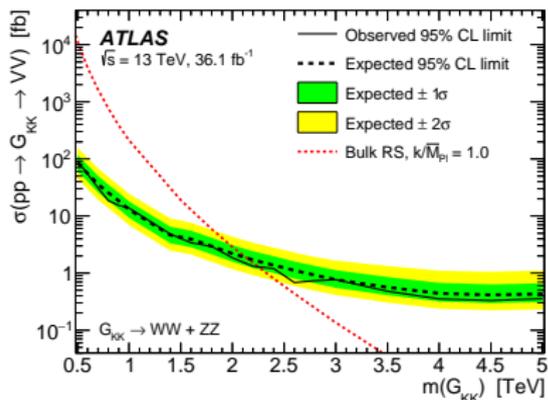
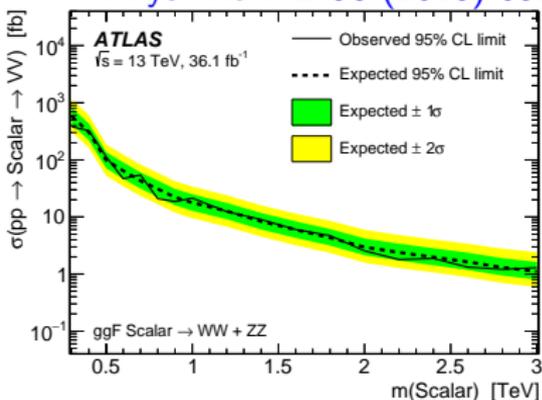
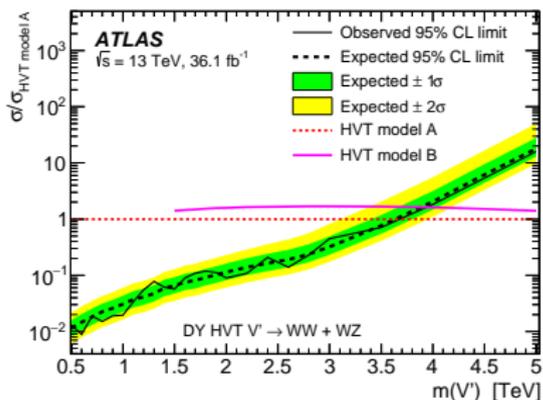
Track assisted mass (left):

Combining track information with calorimeter provides better jet mass resolution

$$m^{\text{TA}} = \frac{p_T^{\text{calo}}}{p_T^{\text{track}}} \times m^{\text{track}}$$

Limits from VV Combination for ggF/DY Production

Phys. Rev. D 98 (2018) 052008



Limits:

- RS Graviton $m = 2.3\text{TeV}$
- HVT Model A $m = 3.7\text{TeV}$
- HVT Model B $m = 4.0\text{TeV}$

Limits from VV Combination for VBF Production

Phys. Rev. D 98 (2018) 052008

