High-mass Diboson Resonances with the ATLAS Detector

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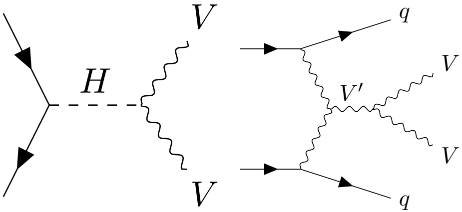
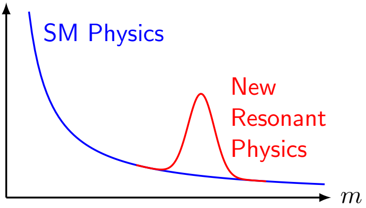
Theory Motivation

- We know Standard Model of Particle Physics is not sufficient to describe some of known phenomena
    - Dark Matter, Gravitation, etc



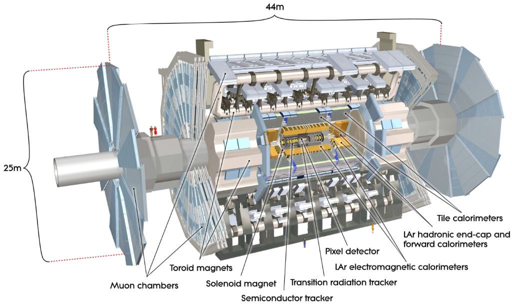


- Various new physics models predict new particles decaying to pairs of W or Z bosons
    - Extended Gauge/Higgs Sectors, Low-Scale Quantum Gravity
- Should appear as resonant detector signature in invariant mass of the bosons

The ATLAS Detector

The Large Hadron Collider (LHC) provides one of the most promising avenues to observe such new physics since it produces $13\mathrm{TeV}\ p-p$ collisions

- Should be able to observe TeV scale resonances if they exist



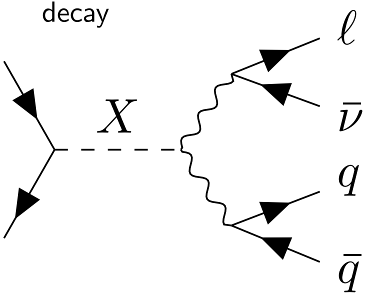
The ATLAS detector is one of the general purpose detectors at the LHC

- In particular ATLAS has good reconstruction of hadronic decays
- Data with $36.1\mathrm{fb}^{-1}$ from 2015-2016 operations extensively analyzed

Semi-leptonic Decays of Diboson Resonances

The "semi-leptonic" decay channel, where one W/Z decays to pairs of leptons and the other W/Z decays to quarks is one of the most sensitive

- Exploits background rejection using leptonic decay
- Maximizes statistics from large branching fraction due to hadronic decay



	WW	WZ	ZZ
all-leptonic	10%	10%	9%
semi-leptonic	44%	43%	42%
all-hadronic	46%	47%	49%

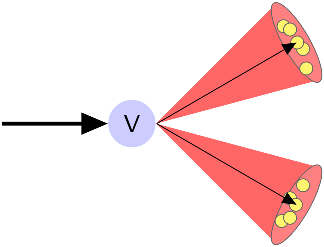
Focusing on 1 charged lepton WV channel, we look for events with:

- One e/μ candidate
- $E_{\mathrm{T,miss}}$ from a ν
- Large hadronic radiation from hadronic decays

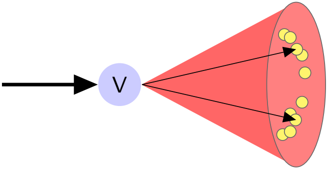
Reconstruction of Hadronic Decays

Hadronic final states are reconstructed by clustering algorithms of the deposited energy clusters in the calorimeter to from objects called "jets"

The opening angle between the two quarks of a decaying boson is approximately $\Delta R \sim \frac{m(V)}{p_T(V)}$



For low-p_{T} boson decaying hadronically the two jets can be distinguished



For high-pt bosons, the decay products can be reconstructed as one large-R jet

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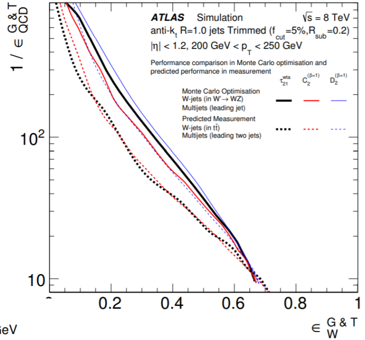
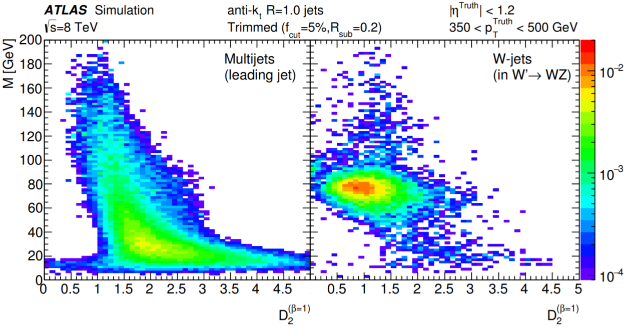
- To suppress backgrounds we exploit the fact that for W/Z decays, most of the radiation is contained in two sub-jets.
- Define a variable $D_2^{\beta=1}$ which describes how much the jet looks like it has two sub-jets

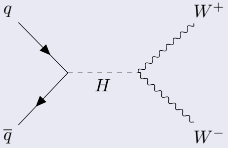




- We combine $D_2^{\beta=1}$ and jet mass to optimize a W/Z tagger with strong background rejection

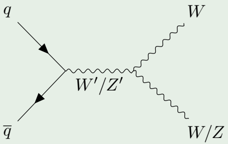
Theory Benchmark Models

Heavy Scalar (Spin-0)



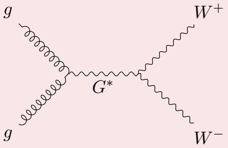
- New heavy Higgs-like boson with negligible width

Heavy Vector Triplet W'/Z' (Spin-1)



- Addition of 3 new nearly-degenerate $SU(2)_L$ bosons
- Couplings to fermions and bosons are free parameters
- Define benchmark couplings which looks like Extended Gauge Sector or Composite Higgs model

Randall-Sundrum Bulk Graviton (Spin-2)

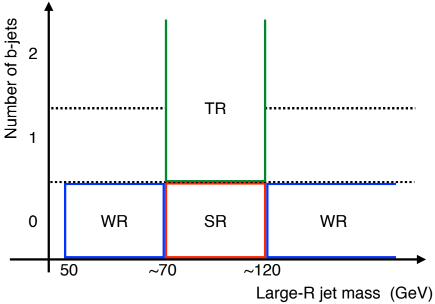


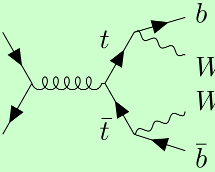
- Graviton propagating through warped extra dimension

Background Estimation

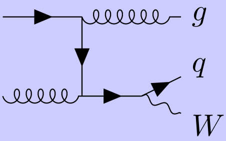
Several other process can fake our signal. Mainly:

- Production of t-quark pairs
- W/Z-bosons produced in association with 2 or more jets



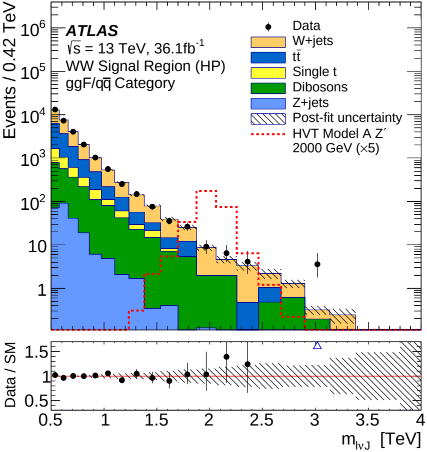


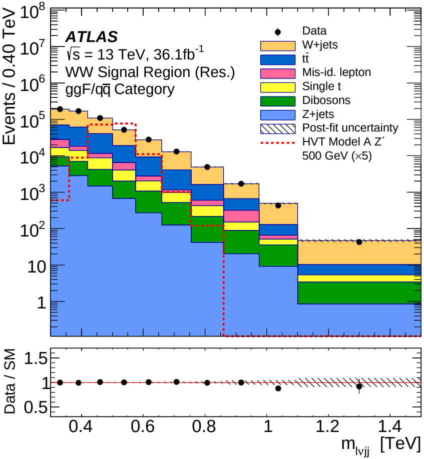
Can be reduced by identifying b-quark decays using multivariate methods



Can be reduced by selecting only a window around W/Z boson mass of reconstructed jets

In the end we test consistency of data against background predictions





$\Longrightarrow$ No excess found

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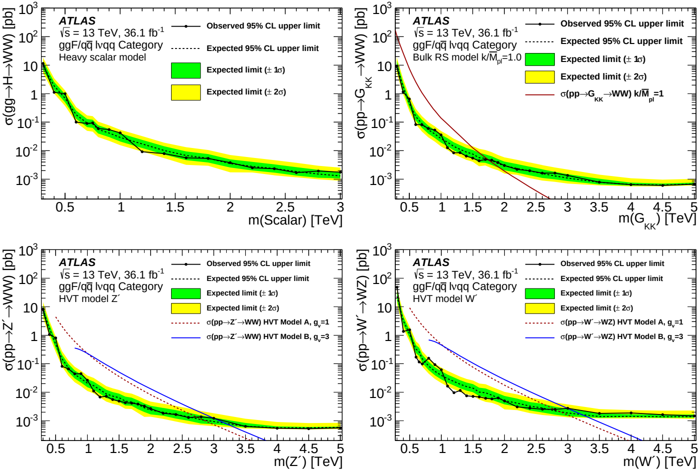
Since no excess, we calculate the 95% CL exclusion limit for each benchmark



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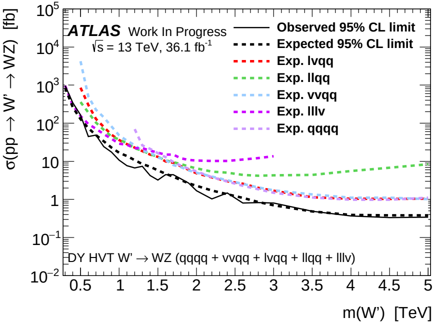
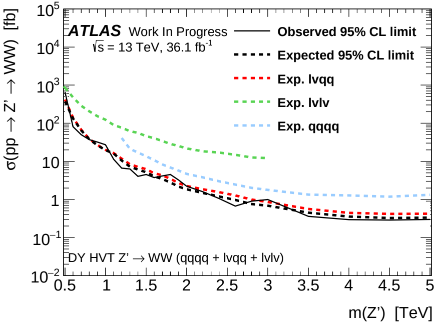
With respect to previous $13\mathrm{TeV}$ results, mass exclusion limits have increased by $390 - 660\mathrm{GeV}$

Every possible diboson resonance final state requires a dedicated analysis





Combining all the individual channels:

- Shows individual analysis sensitivity
- Can improve mass limits by several TeV

Summary

- The ATLAS detector is one of the key tools for possibly discovering new physics at the TeV scale

- One of the promising avenues to search for this new physics is in resonant production of pairs of semileptonic decaying W/Z bosons
  - Predicted by a wide class of models
  - Offer some of the best constraints

- Recent analysis have been able to improve limits by several $100\mathrm{GeV}$ through:
  - Better statistics
  - Exploiting new techniques to reconstruct hadronically decaying W/Z
  - Still in infancy so more room for improvement in calibrations