Diboson Resonance Searches at ATLAS

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- Diboson searches using full Run-2 ATLAS dataset, 139 fb^{-1}

- Search for diboson resonances in hadronic final states
  - arxiv link: 1906.08589
- Search for heavy diboson resonances in semi-leptonic final states
  - arxiv link: 2004.14636
- Search for the $HH \to b\bar{b}b\bar{b}$ process via vector-boson fusion production
  - arxiv link: 2001.05178

Search for diboson resonances in hadronic final states in 139 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector
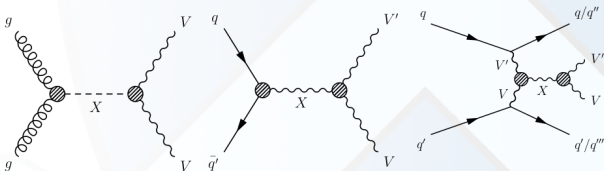
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Search for heavy diboson resonances in semileptonic final states in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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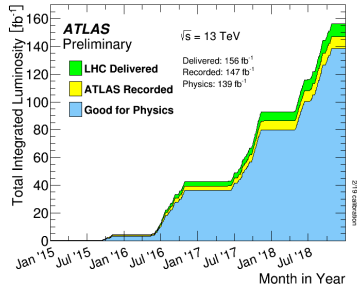
VV Hadronic and Semi-leptonic Searches

- ► VV = WW, WZ or ZZ
  - ► $V_h \to$ large-R jet (merged) or 2 small-R jets (resolved)
  - ► $V_\ell \to \nu\nu$, $\ell\nu$, or $\ell\ell$

- ► Hadronic - $V_h V_h$ (merged)
- ► Semi-leptonic - $V_\ell V_h$

- ► 3 production mechanisms, depending on final state
  - ► gluon-gluon fusion
  - ► Drell-Yan
  - ► vector boson fusion

- ► 3 benchmark models, depending on final state
  - ► Spin-0 radion (Randall-Sundrum)
  - ► Spin-1 vector (Heavy Vector Triplet)
 - ► Spin-2 graviton (Randall-Sundrum)

Hadronic Boson Identification

- Track-CaloCluster (TCC) jets improve substructure resolution
  - Use angular information from tracks and energy scale from calorimeter

- Dedicated W/Z taggers provides background discrimination
  - Tighter cuts at low p_T, where background is highest
  - Hadronic search
    - cuts on mass, D_2, number of tracks
  - Semi-leptonic search
    - Mass cut identifies boson candidates
    - D_2 separates high-purity, low-purity regions
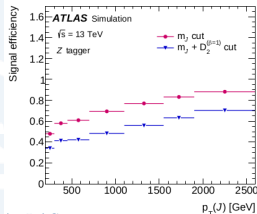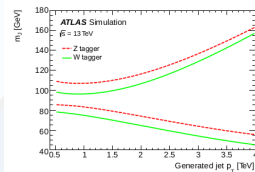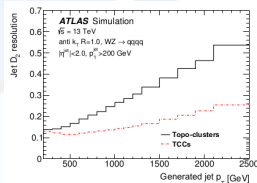
VV Hadronic Background Estimation [1906.08589](1906.08589)

- ▶ Fully hadronic final state
- ▶ Dominant background from QCD
  - ▶ Estimated entirely from data
- ▶ Parametric fit to m_{JJ} spectrum
  - ▶ $\frac{dn}{dx} = p_1(1-x)^{p_2 - \xi p_3} x^{-p_3}$, where $x \equiv \frac{m_{JJ}}{13\text{TeV}}$
  - ▶ ξ chosen to minimise correlation between p_2 and p_3
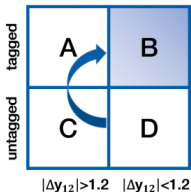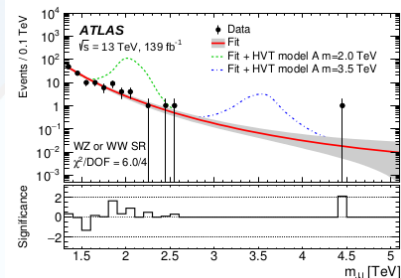

- ▶ Fit validated using untagged data
- ▶ Distribution reweighted to match tagged data
- ▶ Mapping C→A allows estimate of signal region B from D

VV Hadronic Results · 1906.08589

- No significant excess found
- Search sets limits on benchmark models

- Limits for different radion masses

Mass [TeV]	Observed Limit [fb]	Expected Limit [fb]
2.0	5.72	5.75
3.0	1.86	2.85
4.0	1.98	2.34
5.0	1.98	2.02

VV Semi-leptonic Event Categorization   2004.14636
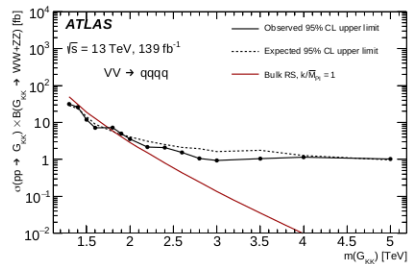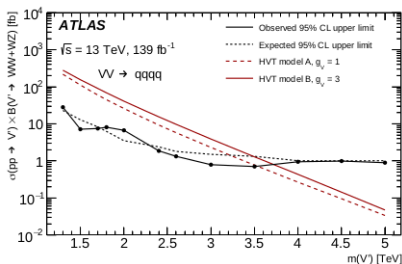
- Semileptonic search has 40 total signal regions
  - 0, 1 or 2 electrons/muons
  - VBF or ggF/DY production
  - merged or resolved V_h
  - merged region split into high/low-purity
  - ggF/DY Z→qq candidates split into b-tagged/untagged

- Recursive Neural Network trained to separate VBF signal from ggF/DY
  - Uses jets not part of V_h reconstruction

- D_2 cut defines high/low-purity regions

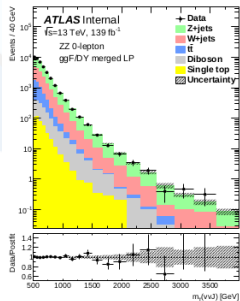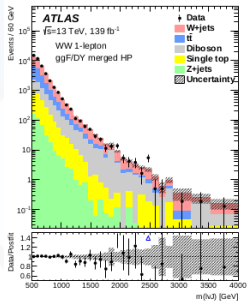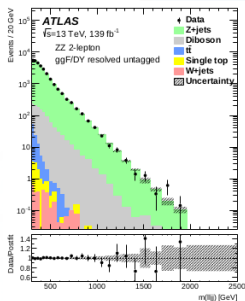- Multivariate b-tagging algorithm creates low-background tagged regions
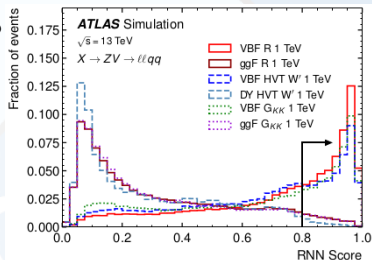
VV Semi-leptonic Backgrounds   2004.14636

- ▶ V+jets dominates background in most regions
- ▶ Control region measurements constrain V+jets, $t\bar{t}$ backgrounds
- ▶ In 0-lepton channel transverse mass used instead of invariant mass
  - ▶ $m_T = \sqrt{(p_T^J + E_T^{\text{miss}})^2 - (\vec{p}_T^{\,J} + \vec{E}_T^{\text{miss}})^2}$

VV Semi-leptonic Results — 2004.14636

- No significant excess found
- Search sets limits on benchmark models for each production mode

- Observed (expected) limits in TeV

| Production process	Radion	HVT		Graviton
		Model	W'	Z'	
ggF/DY	3.2 (2.9)	Model A	3.9 (3.8)	3.5 (3.4)	2.0 (2.2)
		Model B	4.3 (4.0)	3.9 (3.7)	
VBF	–	Model C	–	–	0.76 (0.77)
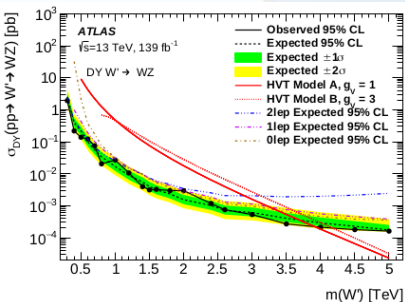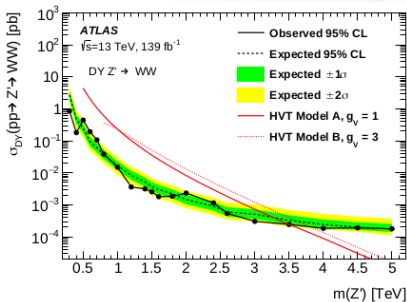
ATLAS
EXPERIMENT

Search for the $HH \rightarrow b\bar{b}b\bar{b}$ process via vector-boson fusion production using proton–proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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VBF HH→4b Search   2001.05178

- ▶ Dedicated search for VBF production
  - ▶ Uniquely sensitive to κ_{2v}
- ▶ Fully hadronic final state
  - ▶ H→ $b\bar{b}$ branching ratio $\sim 58\%$
  - ▶ Multijet background dominates
- ▶ Resolved analysis
  - ▶ 4 b-tagged central jets form Higgs candidates
  - ▶ 2 forward jets from VBF process

- ▶ 2 scalar resonance models considered
  - ▶ Broad, $\Gamma/m_X \sim 10 - 20\%$
  - ▶ Narrow, $\Gamma = 4$ MeV

- ▶ Multivariate b-tagging algorithm suppresses QCD background
  - ▶ Uses tracks associated to jet to look for signs of long-lived b-hadron decays
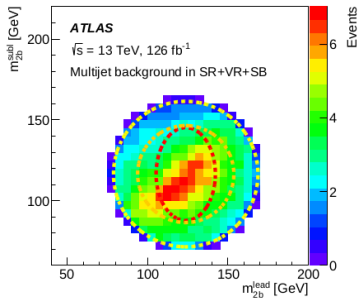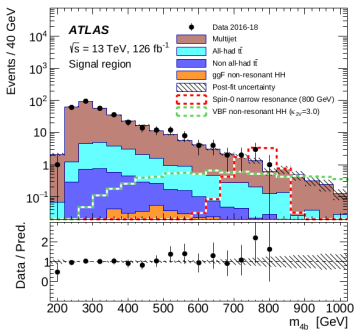 - ▶ Cut applied has 70% tagging efficiency, 0.3% light mis-tag rate
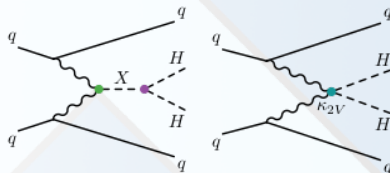
VBF HH→4b Background Estimation   [2001.05178](2001.05178)

- Background estimated using events with 4 central jets, but only 2 b-tags
- 2-tag events weighted to match 4-tag kinematic distributions
- Weights defined in sideband region, away from Higgs peaks

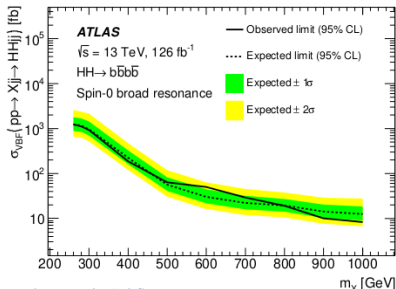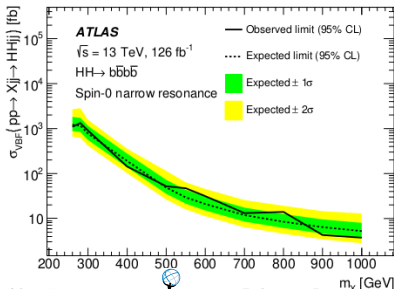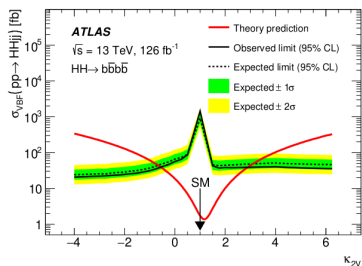- Normalization of multijet and $t\bar{t}$ backgrounds set by sideband fit

- Background estimation checked in validation region, between signal and sideband

VBF HH→4b Results

2001.05178

- No significant excess observed
- Limits set on scalar resonance models and κ_{2v}

Summary

- Diboson searches sensitive to many Beyond-the-Standard-Model theories
- Improved limits set on Randall Sundrum and Heavy Vector Triplet models, as well as model-independent cross-sections
  - More data and improved techniques allow study of rarer production mechanisms, like vector boson fusion
- No significant deviations from SM found
  - Many more results on the way! Stay tuned!
- A few of the other ATLAS results being presented later today:
  - Beyond exclusive leptonic resonances (coming up next!)
  - Searches for resonances in hadronic final states
  - Searches for BSM Higgs
  - Measurements of inclusive multi-boson production
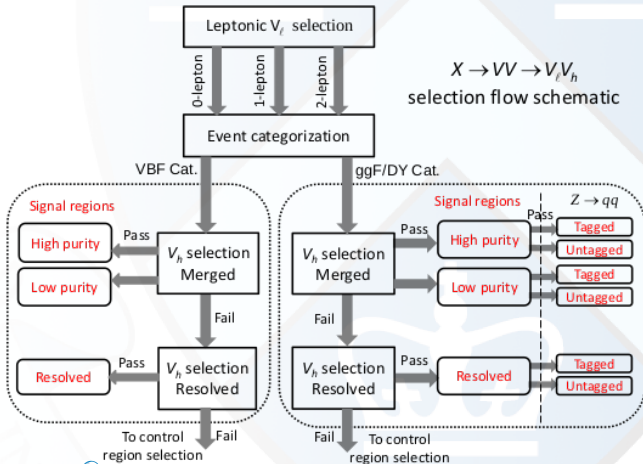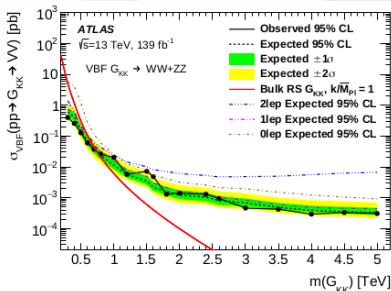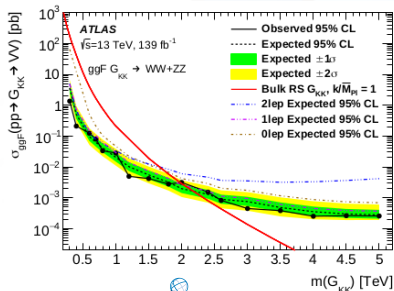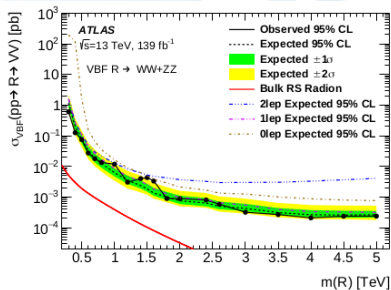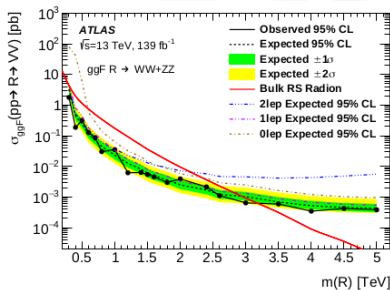
Backup

VV semi-leptonic

- Events categorized by number of leptons, production mechanism, merged/resolved
- RNN trained to separate VBF signal from ggF/DY

$X \to VV \to V_\ell V_h$
selection flow schematic

VV semi-leptonic

VV semi-leptonic