Vector Boson Scattering in Semi-leptonic Final States with the ATLAS Detector

Robert Les
University of Toronto

Lepton Photon 2019

Semi-leptonic Vector Boson Scattering (VBS)

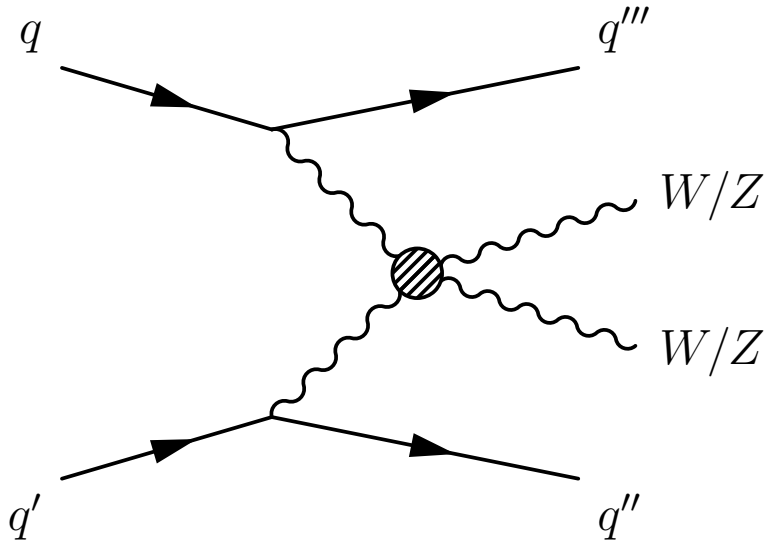
Search in the "semi-leptonic" VBS channel

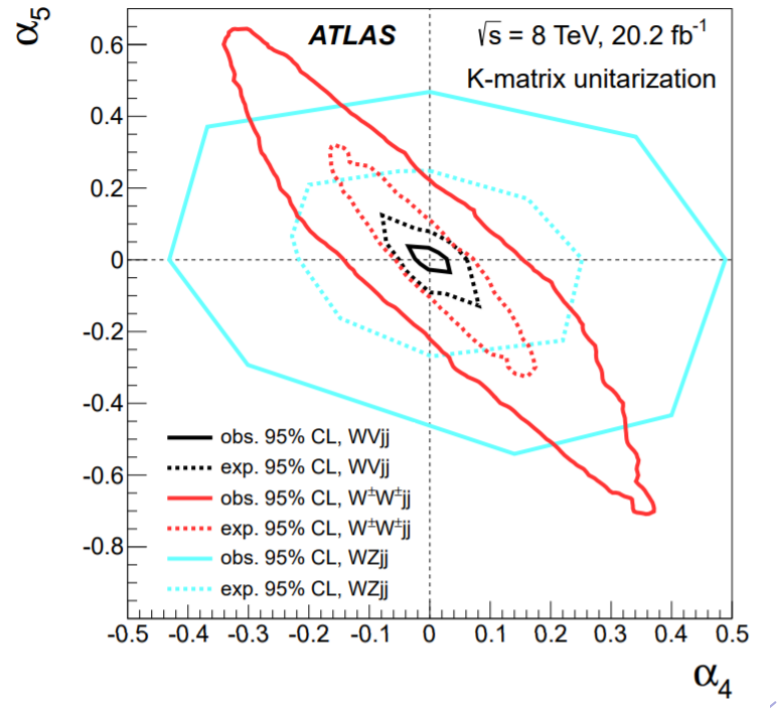
- one hadronic V decay:
  - One or two energetic jets
- one leptonic V decay:
  - $\ell\bar{\ell}$, $\ell + E_{\mathrm{T,miss}}$, or large $E_{\mathrm{T,miss}}$
- Two forward jets which identify the topology

Compromise between competing effects:

- Hadronic decays $\Longrightarrow$ high BR
- Leptonic decays $\Longrightarrow$ less backgrounds

$\ell = e, \mu, \nu$	WW	WZ	ZZ
$\ell\bar{\ell}\ell\bar{\ell}$	5%	6%	7%
$\ell\bar{\ell}q\bar{q}$	30%	33%	36%
$q\bar{q}q\bar{q}$	45%	46%	48%
other	20%	15%	9%





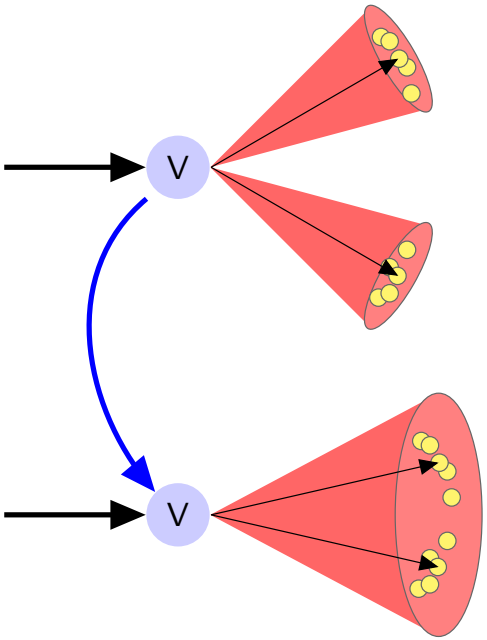
Search Techniques

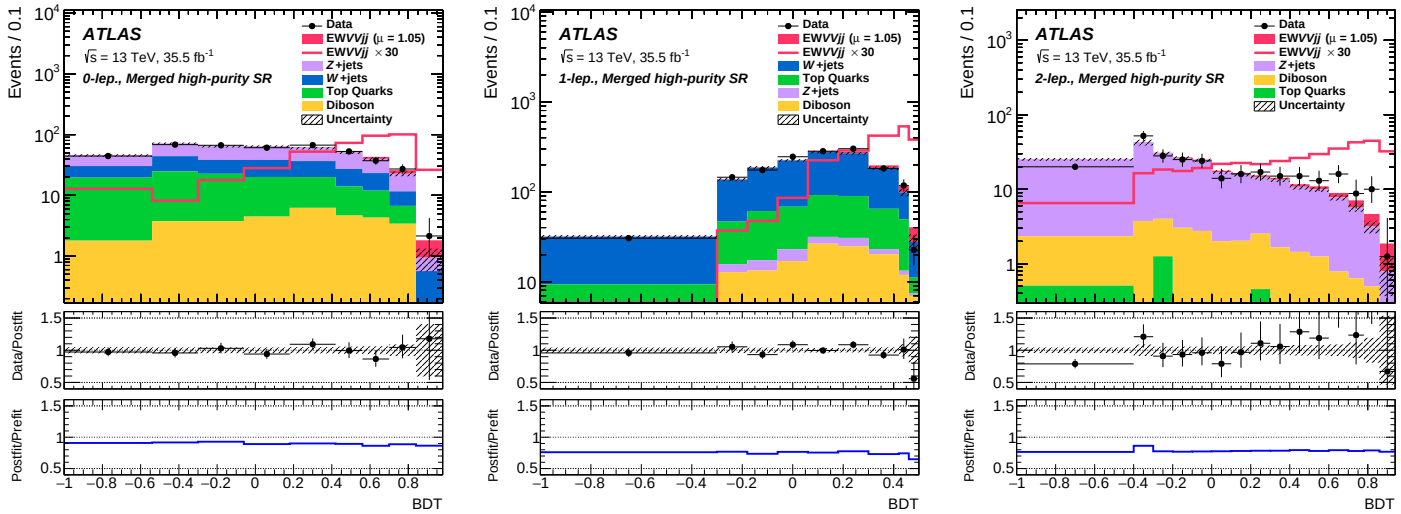
The opening angle:

$$\Delta R \approx 2\frac{m(V)}{p_{\mathrm{T}}(V)}$$

To reduce backgrounds can design a V-tagger:

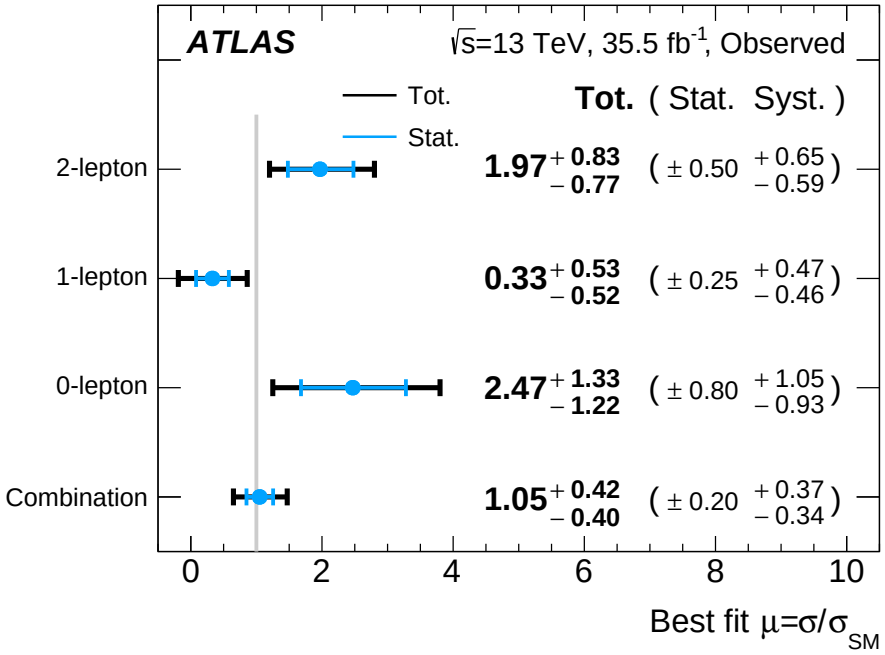
- Mass of the large-R jet
- $D_2^{\beta=1}$ sub-structure variable





Trained a Boosted Decision Tree to optimize search significance in each region

Results



Signal strength:

$$\mu = 1.05^{+0.42}_{-0.40} = 1.05 \pm 0.2(stat)^{+0.37}_{-0.34}(syst)$$

Signal significance:

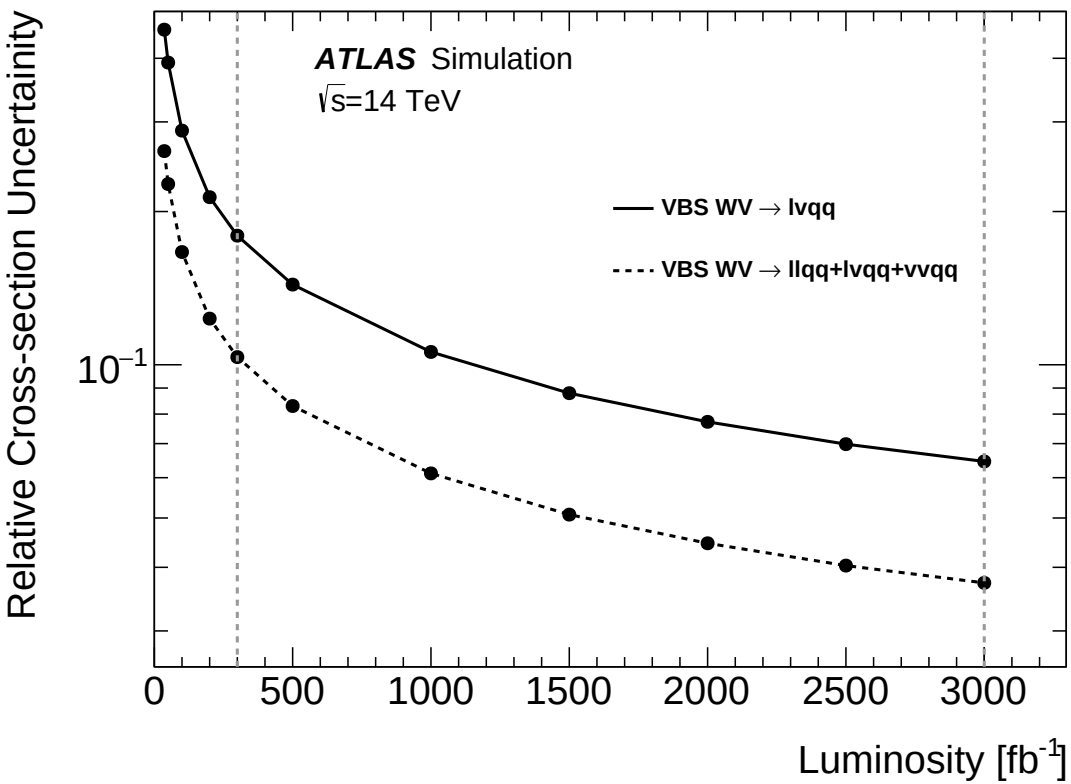
2.7σ observed (2.5σ expected)

Fiducial cross-sections measurements also provided

Fiducial phase space	Predicted $\sigma^{\text{fid,SM}}_{\text{EW}\,VVjj}$ [fb]	Measured $\sigma^{\text{fid,obs}}_{\text{EW}\,VVjj}$ [fb]
Merged	$11.4 \pm 0.7\,(\text{theo.})$	$12.7 \pm 3.8\,(\text{stat.})\,^{+4.8}_{-4.2}\,(\text{syst.})$
Resolved	$31.6 \pm 1.8\,(\text{theo.})$	$26.5 \pm 8.2\,(\text{stat.})\,^{+17.4}_{-17.1}\,(\text{syst.})$
Inclusive	$43.0 \pm 2.4\,(\text{theo.})$	$45.1 \pm 8.6\,(\text{stat.})\,^{+15.9}_{-14.6}\,(\text{syst.})$

Future Prospects

- Uncertainties can be reduced with further statistics and improved modeling
- At the HL-LHC expect precision at the percent level cross-section measurement



Uncertainty source	σ_μ
Total uncertainty	0.41
Statistical	0.20
Systematic	0.35
Theoretical and modeling uncertainties	
Floating normalizations	0.09
$Z+$jets	0.13
$W+$jets	0.09
$t\bar{t}$	0.06
Diboson	0.09
Multijet	0.04
Signal	0.07
MC statistics	0.17
Experimental uncertainties	
Large-R jets	0.08
Small-R jets	0.06
Leptons	0.02
$E_{\mathrm{T}}^{\mathrm{miss}}$	0.04
b-tagging	0.07
Pileup	0.04
Luminosity	0.03

Summary

Vector Boson Scattering is an interesting process which probes the gauge and Higgs structure of the SM:

- Leptonic channels provide cleanest signal
- Semi-leptonic channels probe the tails

Semi-leptonic search utilize modern techniques

- Boosted jet topologies and jet substructure
- Boosted Decision Trees to provide strong discriminants

Future Prospects:

- With full 2015-2018 ATLAS data expect 5σ observation
- Effective Field Theory Interpretations
- In HL-LHC era expect percent level measurements