Measurement of EWK $W\gamma jj$ production at ATLAS

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Tuesday 5th April, 2022

Outline

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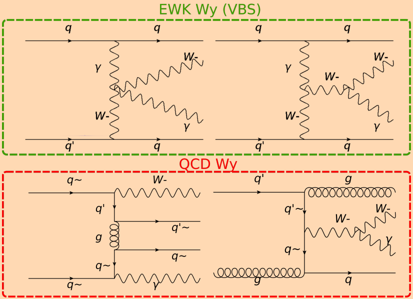
Introduction to $W\gamma$ VBS

Vector Boson Scattering

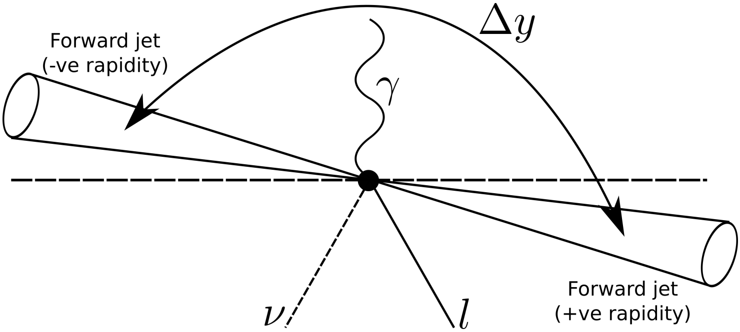
- $2 \rightarrow 2$ scattering of Vector bosons sensitive to gauge boson couplings.
- Allow for searches of new physics through Anomalous Quartic Gauge Couplings.
- Divergent VBS scattering amplitude regulated at high energies by Higgs exchange.
- VBS processes put constraints on fundamental Higgs properties

EWK and QCD $W\gamma jj$ Production

- **EWK $W\gamma jj$ production** is calculated at $\mathcal{O}(\alpha_{EW}^4)$ at amplitude level and includes diagrams involving a t-channel exchange of an EWK boson (W, γ, Z).
- **QCD $W\gamma jj$ production** has no EWK boson exchanged in the t-channel and is calculated at $\mathcal{O}(\alpha_s^2\alpha_{EW}^2)$ at amplitude level.



VBS Phenomenology



Key Electro-Weak VBS features

1. Two forward jets with large p_{T}, m_{jj} and Δy_{jj}.
2. Little hadronic activity in central region. Quantified by $N_{\mathrm{gapjets}} \equiv$ number of jets in rapidity gap Δy.
3. Centrally produced bosons relative to jets. Quantified by centrality $\xi_{W\gamma}$.
   $\xi_{W\gamma} \equiv \frac{y_{W\gamma} - \frac{1}{2}(y_{j1}+y_{j_2})}{|\Delta y_{jj}|}$.

EWK Wγ measurement

Analysis goals

- Observe electroweak $W\gamma jj$ production at 13TeV at the ATLAS detector (already observed by CMS)
- Calculate differential cross-section of VBS sensitive variables
- Put constraints on anomalous gauge interactions defined through an EFT

Observables

Measurement observables chosen to facilitate:

1. Characterising the Wγ-VBS process.
2. Probing sensitivity to EFT parameters.

The observables we are measuring are: m_{jj}, $p_{\mathrm{T}\,jj}$, $\Delta\phi_{jj}^{\mathrm{signed}}$.

EFT Constraints

$$\mathcal{L}_{\mathrm{eff}} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i \tag{1}$$

- 3-point and 4-point interactions probed through dim-6 and dim-8 operators.
- EFT-dependent theoretical predictions and measured differential cross-sections used to define a profile likelihood.
- Perform profile likelihood fit to obtain expected and observed confidence limits on EFT Wilson coefficients.

Event Selection

Event Selection criteria

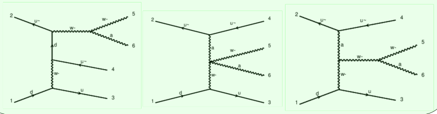
VBS Enhanced Phasespace:

- Two hard leading jets
- Large di-jet invariant mass
- Large rapidity gap between the two jets

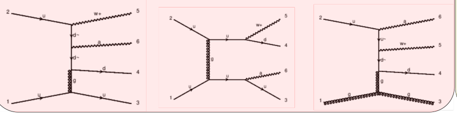
Reducible background suppression:

- Second lepton veto
- b-jet veto
- Z veto
- Tight and isolated lepton and photon

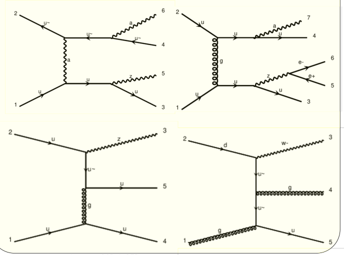
Electroweak Wγ Signal



Irreducible Strong Wγ Background



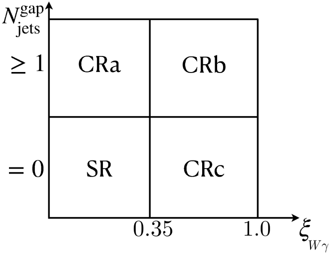
Reducible Non-Wγ Background



Signal extraction method

- Poorly modelled Strong $W\gamma$ background in VBS enhanced regions $\Rightarrow$ important to derive data-driven corrections.
- Use VBS characteristics (low N_{gapjets}, low $W\gamma$ centrality) to define Signal and Control Region(s). Define likelihood function to simultaneously constrain background and extract signal strength.
- 1CR $\Rightarrow$ Have $2N_{\text{bins}}$ DoF. Need N_{bins} free parameters to extract signal and N_{bins} free parameters to constrain background. No DoF left for residual corrections.
- Method pioneered by ATLAS VBF-Z analysis.

Three Control Region Fit



$$\ln \mathcal{L} = -\sum_{r,i} \nu_{r,i}(\theta) + \sum_{r,i} N_{r,i}^{\text{data}} \ln \nu_{r,i}(\theta) - \sum_{s} \frac{\theta_s^2}{2}$$

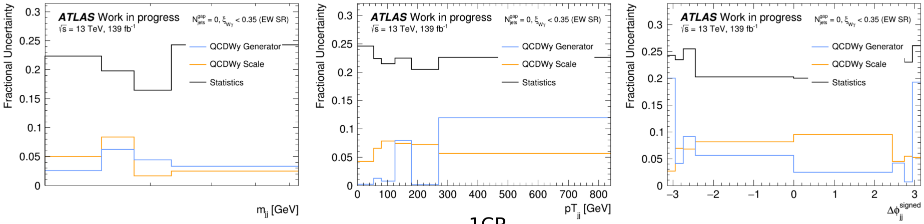
$$\nu_{r,i} = \mu_i \nu_{r,i}^{\text{EW,MC}} + \nu_{r,i}^{\text{strong}} + \nu_{r,i}^{\text{other,MC}},$$

$$\nu_{\text{CRa},i}^{\text{strong}} = b_{\text{L},i} \nu_{\text{CRa},i}^{\text{strong,MC}}, \quad \nu_{\text{CRb},i}^{\text{strong}} = b_{\text{H},i} \nu_{\text{CRb},i}^{\text{strong,MC}},$$

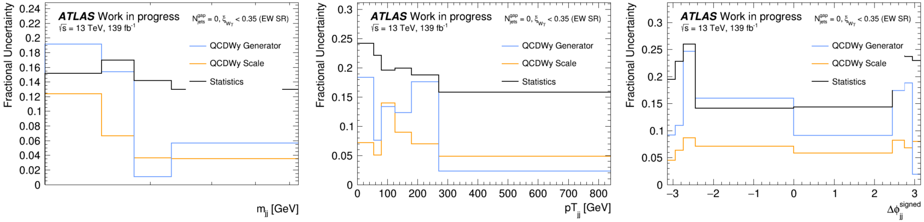
$$\nu_{\text{SR},i}^{\text{strong}} = b_{\text{L},i} f(x_i) \nu_{\text{CRa},i}^{\text{strong,MC}}, \quad \nu_{\text{CRC},i}^{\text{strong}} = b_{\text{H},i} f(x_i) \nu_{\text{CRc},i}^{\text{strong,MC}}.$$

Preliminary results - Modelling and Stat Uncertainties

3CR

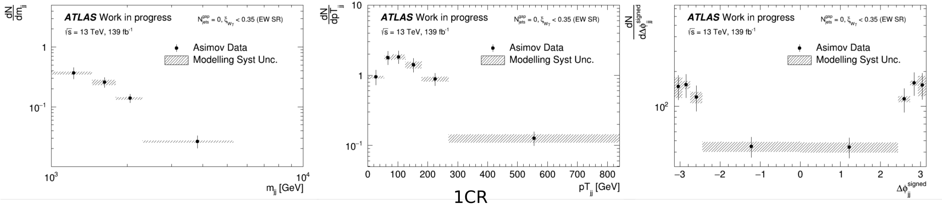


1CR

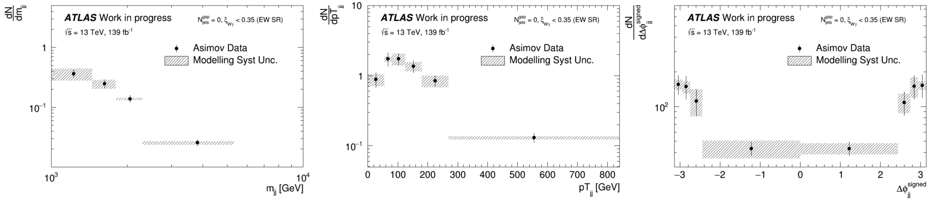


Preliminary results - Relative Yields

3CR



1CR



Summary

- The study of VBS processes allows for searches of new physics through aQGCs and can put constraints on fundamental Higgs properties.
- The ATLAS VBS Wγ analysis aims to make an observation of the EWK production of $W\gamma jj$ in a VBS enhanced phase-space.
- The feasibility of a differential cross-section measurement is being determined using 3CR and 1CR fits to extract a signal and constrain the dominant irreducible background.
- We aim to measure three jet observables: m_{jj}, $p_{\mathrm{T}jj}$, and $\Delta\phi_{jj}^{\mathrm{signed}}$.
- Unfolding of the differential measurement still needs to be performed.
- Full set of systematic uncertainties on differential yield and statistical resolution studies of systematic uncertainties still need to be obtained.

Backup I

Backup Slides