Measurement of the electroweak production of dijets in association with a Z boson

UCL

Introduction

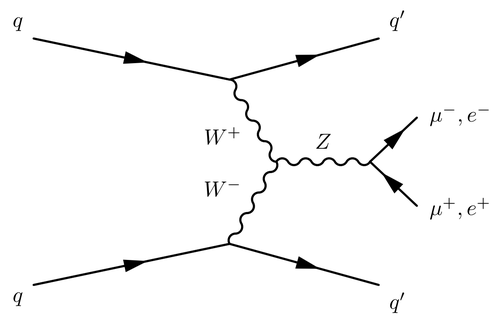
We present the observation of electroweak Zjj production beyond the 5σ-level [1], which is the first observation at that significance of a process involving a vector boson fusion (VBF) diagram.

The VBF Z process is interesting to study because of its similarity to the VBF production of a Higgs boson as well as its sensitivity to new physics via the WWZ triple gauge coupling.

Signal

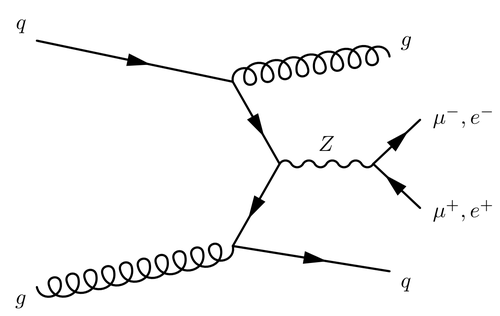
We are looking for the electroweak (EW) production of a dijet and a Z via the t-channel exchange of a vector boson.

This includes the vector boson fusion process (shown below) which is one of seven diagrams that define our signal.



Background

The dominant Zjj production mode at the LHC is via the Drell-Yan process with additional jets arising from the strong interaction (example diagram shown below).



The strong Zjj cross section is **100 times larger** than the electroweak signal process.

Strategy and selection

We select events requiring a Z-boson candidate with a tight invariant mass cut and at least two high-p_{T} jets.

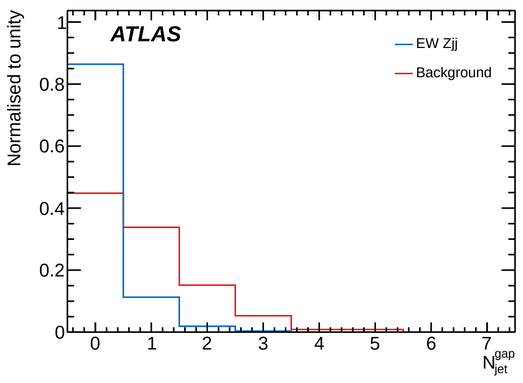
A veto on the number of jets in the rapidity interval between the two leading jets (cf. interval-jet distribution under 'Main signal features') is used to split this baseline selection into a signal-enhanced and a signal-suppressed region.

The EW Zjj component is extracted in the signal-enhanced search region using a **two-component template fit to the dijet invariant mass** spectrum.

The signal-suppressed control region is used to **constrain the shape of the background** model.

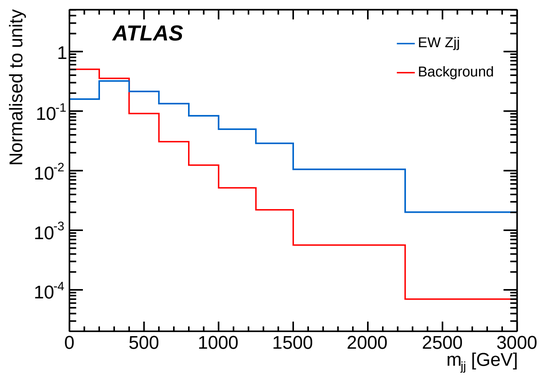
Main signal features

Due to the **colourless exchange of vector bosons** (see VBF diagram above), there tend to be **no additional jets in the rapidity gap** between the two leading jets (see particle-level shape comparison below).



Number of interval jets

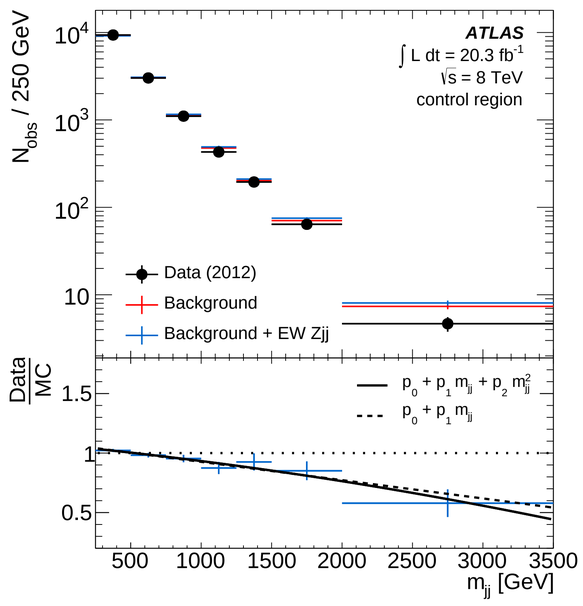
The jets tend to be produced with high p_{T} and together they balance the Z. This results in **two forward jets with large dijet invariant mass** (see particle-level shape comparison below).



Dijet invariant mass

Control region

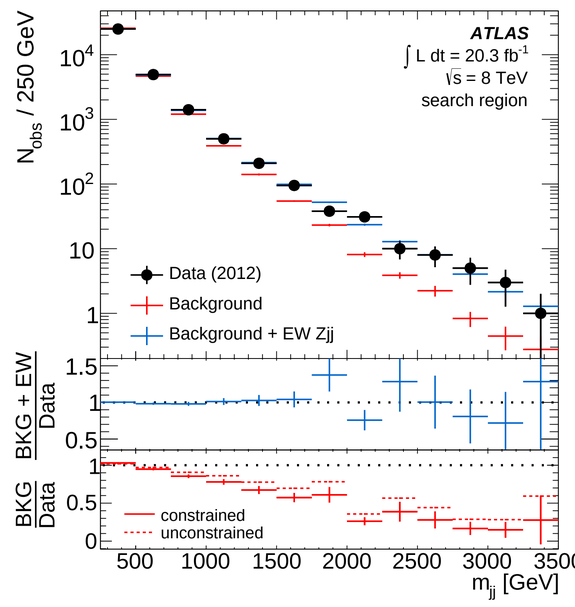
The ratio of data to Monte Carlo in the control region is used to obtain a reweighting function for the background model in the search region.



This data-driven correction **reduces both experimental and theoretical systematic uncertainties** on the background model.

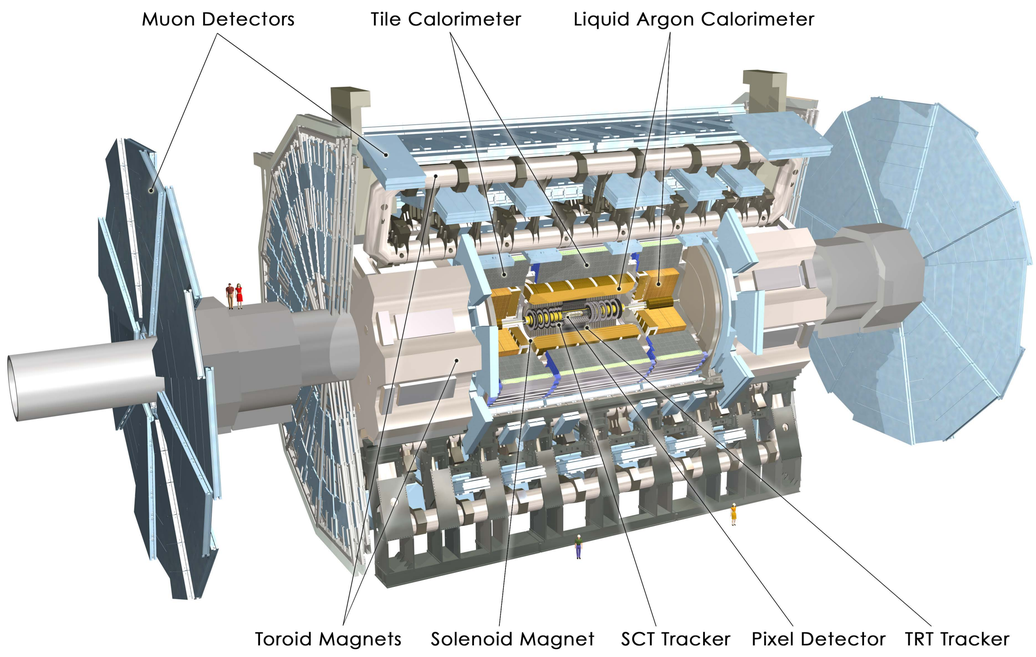
Search region

The fit to the data is performed using log-likelihood maximisation, allowing the normalisation of the templates to float.



The **tail of the dijet invariant mass distribution is most sensitive to the signal** and least sensitive to the background normalisation.

The ATLAS detector



Systematic uncertainties

$$\sigma_{\mathrm{EW}} = \frac{N_{\mathrm{EW}}}{\int \mathcal{L}\,\mathrm{d}t \cdot \mathcal{C}_{\mathrm{EW}}} \quad \text{where} \quad \begin{array}{lll} N_{\mathrm{EW}} & - & \text{number of signal events fitted for} \\ \int \mathcal{L}\,\mathrm{d}t & - & \text{integrated luminosity} \\ \mathcal{C}_{\mathrm{EW}} & - & \text{correction factor based on particle- to detector-level ratio} \end{array}$$

A breakdown of the various systematic uncertainties for N_{EW} and $\mathcal{C}_{\mathrm{EW}}$ is given below:

Source	ΔN_{EW}		$\Delta \mathcal{C}_{\mathrm{EW}}$	
	Electrons	Muons	Electrons	Muons
Lepton systematics	—	—	±3.2 %	±2.5%
Control region statistics	±8.9 %	±11.2 %	—	—
Jet energy scale	±5.6 %		$^{+2.7}_{-3.4}$ %	
Jet energy resolution	±0.4 %		±0.8 %	
Pileup jet modelling	±0.3 %		±0.3 %	
Jet vertex fraction	±1.1 %		$^{+0.4}_{-1.0}$ %	
Signal modelling	±8.9 %		$^{+0.6}_{-1.0}$ %	
Background modelling	±7.5 %		—	
Signal/background interference	±6.2 %		—	
Parton density function	$^{+1.5}_{-3.9}$ %		±0.1 %	

Detector-corrected fiducial cross sections for EW Zjj production

Result for search region ($m_{jj} > 250$ GeV):

Measurement: **$54.7 \pm 4.6\,(\mathrm{stat})\,^{+9.8}_{-10.4}\,(\mathrm{syst}) \pm 1.5\,(\mathrm{lumi})$ fb**

SM prediction: $46.1 \pm 0.2\,(\mathrm{stat})\,^{+0.3}_{-0.2}\,(\mathrm{scale}) \pm 0.8\,(\mathrm{PDF}) \pm 0.5\,(\mathrm{model})$ fb

Result for search region with $m_{jj} > 1$ TeV:

Measurement: **$10.7 \pm 0.9\,(\mathrm{stat}) \pm 1.9\,(\mathrm{syst}) \pm 0.3\,(\mathrm{lumi})$ fb**

SM prediction: $9.38 \pm 0.05\,(\mathrm{stat})\,^{+0.15}_{-0.24}\,(\mathrm{scale}) \pm 0.24\,(\mathrm{PDF}) \pm 0.09\,(\mathrm{model})$ fb

Both measurements are in good agreement with the theoretical predictions from POWHEG.

Summary

- measurement of electroweak Zjj cross section in two fiducial regions
- results also used to set limits on anomalous triple gauge couplings
- inclusive cross sections and differential distributions measured and corrected for detector effects in five fiducial regions with varying sensitivity to EW component

References

[1] ATLAS Collaboration, *Measurement of the electroweak production of dijets in association with a Z-boson and distributions sensitive to vector boson fusion in proton-proton collisions at $\sqrt{s} = 8$ TeV using the ATLAS detector*, submitted to JHEP, [arXiv:1401.7610]

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