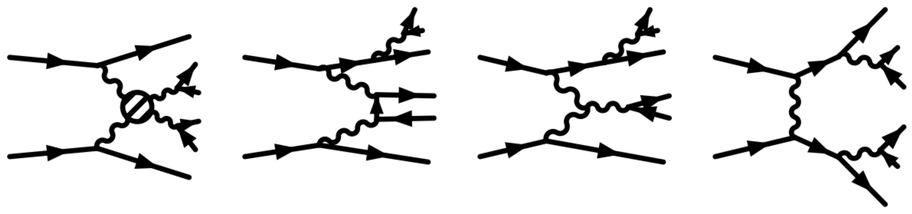
Study of Vector-Boson Scattering in $pp \to WZjj \to \ell^{\pm}\overset{(-)}{\nu}\ell'\bar{\ell}'jj$

Introduction

Measuring vector-boson scattering is one of the main goals of the LHC. It is required to be existent in the Standard Model and therefore has to be measured to confirm this theory. Additional resonances could be present in the quartic boson interaction, leading to anomalous quartic gauge couplings visible in vector-boson scattering processes.
Vector-boson scattering is defined theoretically as gauge invariantly not separable, electroweak order six processes and named $VVjj\text{-}EW$. Some example Feynman diagrams are shown below.

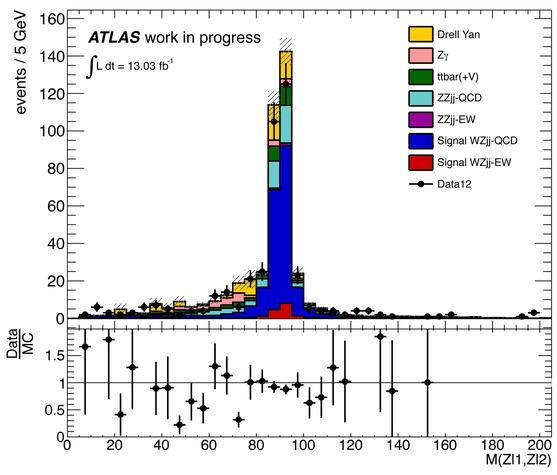


Vector-Boson Scattering Channels

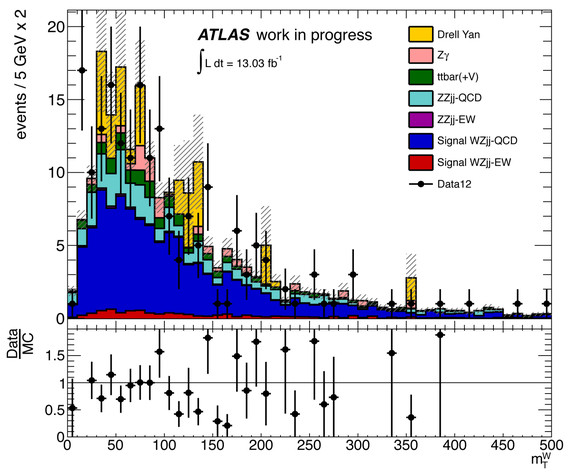
There are different final states requiring separate, optimized studies depending on the involved vector-bosons and their decay. The most promising channels for this first-ever measurement are:

- $WZjj\text{-}EW$ (shown here): Vector-boson scattering with a W and a Z in the final state, decaying leptonically into three leptons and one neutrino. This channel has a clean signature of three leptons and missing transverse energy in the detector. But there is a very large background from non vector-boson scattering WZ production ($\sigma = 9.8$ pb, $\sigma(WZjj\text{-}EW) = 18.4$ fb, 8 TeV, $m(\ell^+, \ell^-) > 5$ GeV).
- $W^{\pm}W^{\pm}jj\text{-}EW$: Vector-boson scattering with two like-sign W bosons in the final state, decaying leptonically into two leptons and two neutrinos. In this channel, the cross-section of non vector-boson scattering $W^{\pm}W^{\pm}$ is of the same order of magnitude as the vector-boson scattering contribution ($\sigma = 15.3$ fb, $\sigma(W^{\pm}W^{\pm}jj\text{-}EW) = 14.3$ fb), but other backgrounds are dominating.

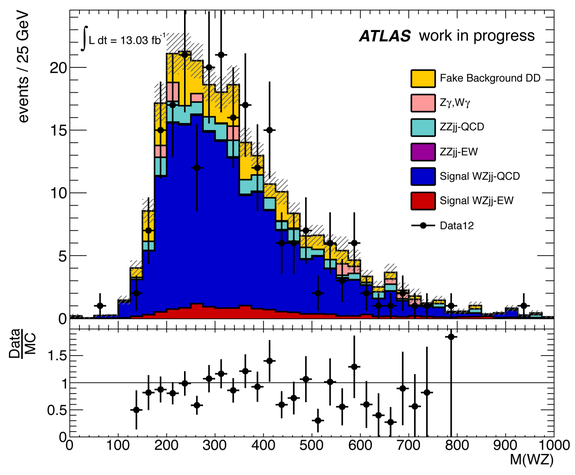
Selection of W and Z Vector-Boson Candidates



Events with at least two same-flavour, opposite-charge and good leptons are selected to require at least one Z boson in the event. In addition, the event must have a relatively large missing transverse energy of $E_{\mathrm{T}}^{\mathrm{miss}} > 25$ GeV and contain at least one additional lepton selected with a more advanced lepton finder. Shown in the left plot is the invariant mass of the lepton pair closest to the PDG mass of the Z boson after the W and Z selection.

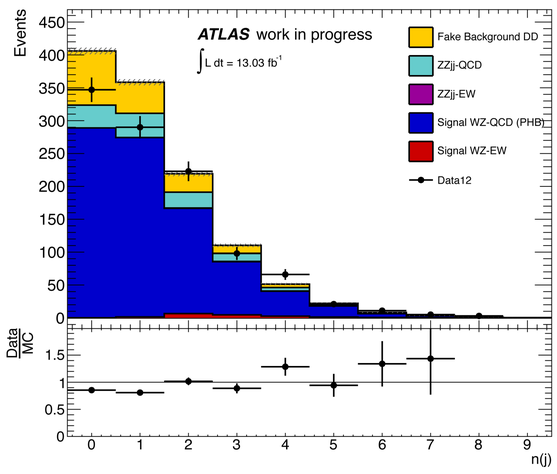


The peak compatible with the Z boson mass is well visible. For the final selection, this invariant mass is required to be within a window of 15 GeV to the PDG Z mass to avoid mis-selections. The middle plot shows the transverse mass of the selected W boson, defined as the invariant mass of the additional lepton with the largest p_{T} and the missing transverse energy in the transverse plane (z component of the lepton is set to zero).

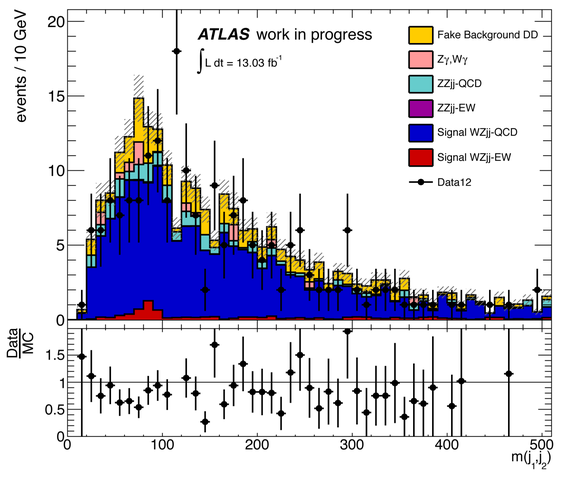


Shown in the plot on the right-hand side is the invariant mass of the selected WZ boson pair. The not measurable z component of the neutrino is calculated by using the PDG W boson mass. The important background where the W lepton is faked from a jet is estimated from data in this plot. This is important, because this background is not very well modeled by simulation.

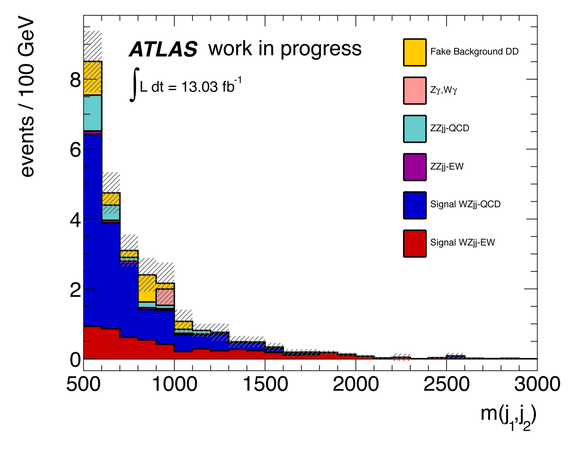
Jet Multiplicity and Tagging Jets



This plot shows the number of jets in the event after selection of the W and Z candidates. Jets are reconstructed with the anti-kt jet clustering algorithm. To suppress jets from pileup, just jets with a high probability to stem from the primary vertex (Jet-Vertex Fraction > 0.5) and with a transverse momentum of at least 25 GeV are counted.



The two remaining plots show the invariant mass of the two jets with the largest transverse momentum. At the left-hand side, low values up to $m_{jj} = 500$ GeV are shown from data and simulation. This is a region to study the consistency of the selection. The first-ever measurement of the combined $WZjj\text{-}EWQCD$ process is possible in this region with the data of 2012.



At the right-hand side, the region with large values of m_{jj} is shown. Due to tagging-jet signature of vector-boson scattering, $WZjj\text{-}EW$ can be extracted and measured in this region. With a reasonable cut of $m_{jj} > 800$ GeV, about 6 vector-boson scattering events and about 8 background events are expected with the full 2012 dataset.

Contact Details, Papers and Talks

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- *Analysis of Standard Model Weak Boson Scattering* $qq \to qqVV$, LHC to Terascale Physics Workshop, Talk P. Anger http://iktp.tu-dresden.de/IKTP/pub/11/11_11_23_LHC_to_Terascale_Physics_Workshop.pdf
- *Study of Vector Boson Scattering with Pileup with the ATLAS Detector at the LHC*, Diploma Thesis P. Anger, http://cds.cern.ch/record/1308417
- *Physics at a High-Luminosity LHC with ATLAS*, P. Anger, M. Kobel, et al., Briefing book for the European Strategy for Particle Physics
- European strategy *Implications of LHC results for TeV-scale physics: signals of electroweak symmetry breaking*, P. Anger, M. Kobel, U.Schnoor, et al., Open Symposium of the European Strategy Preparatory Group, Krakow, Poland

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