PROCEEDINGS OF SCIENCE

Studies of WW and WZ production at CDF

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Diboson production in $p\bar{p}$ collisions at 1.96 TeV are studied in samples of $\sim$ 3-6 fb^{-1} of data using leptons, jets and missing E_T. Fully leptonic decays as well as semi-leptonic decays are measured since it is important to investigate various signatures as associated production of Higgs bosons is topologically similar. Measured production cross sections are in good agreement with Standard Model predictions and the limits on the anomalous triple gauge boson couplings are competitive with the ones measured by experiments at the LEP.

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1. Introduction

Diboson production is of great interest because it provides unique opportunity to test the Standard Model (SM) at the TeV scale, it constitutes a very important background to Higgs and SUSY searches and it is a probe to new physics through deviations of Triple Gauge Couplings (TGCs) from Standard Model predictions. In this paper we examine diboson production (WW, WZ, ZZ) in their leptonic and semi-leptonic final states.

2. Diboson production in leptonic final state

These final states are characterized by low branching ratio and clean yields due to the low background. All the analysis use an improved lepton definition to increase acceptance.

2.1 WW cross section and TGC

We measured the WW production cross section in the two charged lepton (e or μ) and two neutrino final state using 3.6 fb^{-1} of integrated luminosity[1]. The WW cross section is the extracted using a binned fi to the likelihood ratio formed from Matrix Element probabilities of signal and background shapes to the data. The measured cross section is $12.1 \pm 0.9(\text{stat.})^{+1.6}_{-1.4}(\text{syst.})$ pb, that is in good agreement with the SM prediction and represents the most precise measurement up to date.

We also set limits on the trilinear gauge couplings of the WW production. The analysis examines the p_T distribution of the leading lepton and performs a fit in order to determine limits on the couplings. The HISZ parameterization [2] is used to make 3 independent parameters ($\lambda^Z = 0$, $g_1^Z = \kappa^\gamma = 1$ in SM). We set the limits $-0.17 < \lambda^Z < 0.17$, $-0.26 < \Delta g_1^Z < 0.35$, and $-0.68 < \Delta\kappa^\gamma < 0.77$ where Δg_1^Z and $\Delta\kappa^\gamma$ are the deviations of the parameters from the SM values.

2.2 WZ cross section

To search for WZ production we look for events with 3 electrons or muons plus $\not{E}_T$ (missing transverse energy) in 1.9 fb^{-1} of integrated luminosity [3]. Because this has a small branching ratio, we use an optimized lepton selection. The ratio between the WZ cross section and the $Z \to \ell\ell$ is measured to reduce the systematic uncertainties and the final cross section is extracted using the theoretical cross section for $Z \to \ell\ell$. The measured cross section is 4.1 ± 0.7 pb, compatible with the SM prediction.

3. Diboson production in semi-leptonic final state

Diboson production in final state with jets is much more challenging due to large background from V+jets (V = Z, W). Those events are interesting because their topology is similar to events where a Higgs boson is produced in association with a W or a Z, allowing diboson measurements to provide an important step towards possible future measurement of Higgs production.

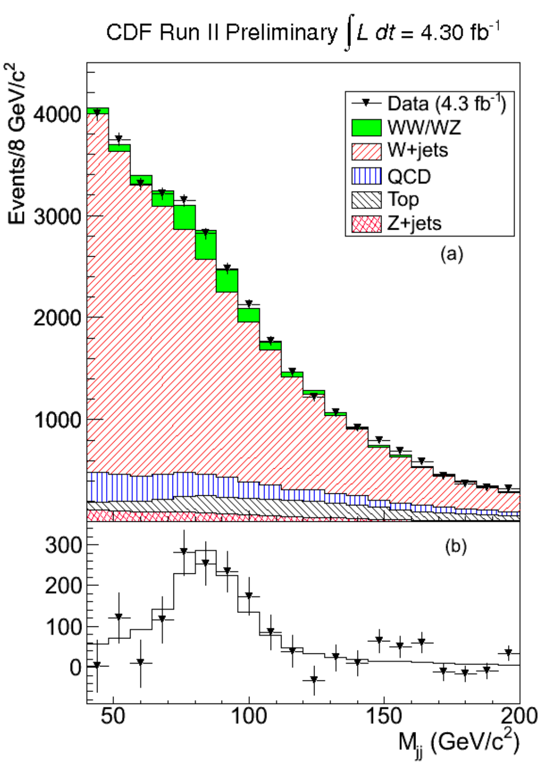

Figure 1: Dijet invariant mass distribution of reconstructed W/Z $\rightarrow jj$ candidates compared to the fitted signal and background components.

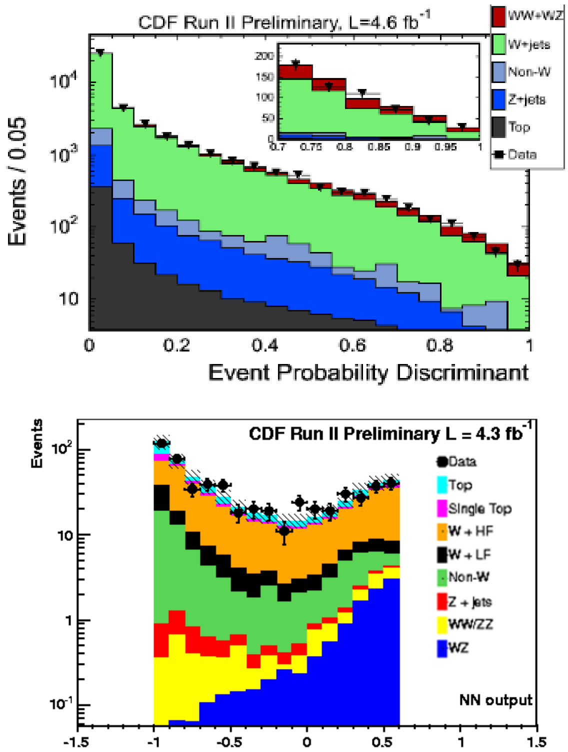

Figure 2: Top: Observed EPD distribution superimposed on expected distribution from simulation. Bottom: Fitted NN output for WZ search.

3.1 VV in met+jets

We measured the diboson cross-section using events with large $\not{E}_T$ ($>$ 60 GeV) and two jets with E_T above 25 GeV[4]. Due to limited energy resolution we cannot distinguish between WW, WZ and ZZ events so what we measure is really a sum of all these processes in our selection window. No cut on number of leptons in the event is performed therefore we are also sensitive to lepton decays of the gauge bosons. The QCD contribution, which is large in this channel, is heavily suppressed through novel algorithms related to $\not{E}_T$ significance. We extract the signal from the background using the invariant mass distribution of the two jets in the event. The extraction of the signal does not use the theoretical calculation of the V+jets cross section and its invariant mass shape is cross checked with γ+jets events from the data, hence considerably reducing the systematic uncertainty on the shape of this main background. The significance of the production is 5.3σ and the cross section is measured to be $\sigma(p\bar{p} \rightarrow VV+X) = 18.0 \pm 2.8(\text{stat.}) \pm 2.4(\text{syst.}) \pm 1.1(\text{lum.})$ pb, in good agreement with the SM expectations.

3.2 $WW/WZ \rightarrow \ell\nu jj$

Two different approaches are used to measure the cross section in this channel. They both select signal samples requiring one identified lepton with $E_T > 20$ GeV, significant $\not{E}_T > 25$ GeV and jets.

The first one uses a data sample corresponding to approximately 4.3 fb^{-1} of integrated luminosity to reconstruct WW/WZ events [5]. The diboson signal is extracted from the background using a χ^2 fit of the invariant mass distribution, M_{jj}, of the two leading jet separately for the electron and muon samples. This simple method allows to search for a signal peak over a smooth background. The fit is performed in the M_{jj} region from 28 to 200 GeV/c^2 and estimates the fractions of signal, QCD and EWK backgrounds using M_{jj} templates obtained from the CDF full simulation (signal and EWK) and data (QCD). The total W+jets contribution is a free parameter of the fit while the normalization of the other background is Gaussian constrained to either their expected cross section ($t\bar{t}$, single top), the measured cross section (Z+jetS) or from a separate fit to the $\not{E}_T$ distribution to the data (QCD normalization). The fit is shown in Fig. 1 and corresponds to a statistical significance of 5.2σ (5.1σ expected). We measure $\sigma(\text{WW/WZ}) = 18.1 \pm 3.3(\text{stat.}) \pm 2.5(\text{syst.})$.

The other approach uses 4.6 fb^{-1} and takes advantage of a multivariate technique to exploit all the information in the event [6]. Event probability densities are calculated under the signal and background hypotheses using a set of measured variables of each event (the 4-vectors of the lepton and the two jets). Then the probabilities are used to construct a discriminant variable for each event, referred to as the Event Probability Discriminant, or EPD. To quantify the $WW+WZ$ content in the data, a binned maximum likelihood fit to the data is performed(see Fig. 2 top). The background normalizations (except for W+jets that is a free parameter) are Gaussian constrained in the fit. Pseudo-experiments are carried out to determine the significance of the excess that is found to be 5.4σ (5.1σ expected). The measured cross section is $16.5^{+3.3}_{3.0}$ pb, compatible with the previous one and with the SM prediction.

4. $WZ \to \ell\nu b\bar{b}$

After the observation of diboson in the semileptonic final state, the mandatory step toward Higgs searches is the search for $WZ \to \ell\nu b\bar{b}$ [7]. Events are selected requiring one lepton, $\not{E}_T > 20$ GeV and two jets. The two jets are identified to come from a b quark using a Neural Net (NN) algorithm that uses both the lifetime information as well as the lepton information. Discrimination between the WZ signal and the comparatively large backgrounds in the W + 2 jet bin is improved through the use of a neural network (see Fig. 2 bottom). The analysis sets a limit based on 4.3 fb^{-1} of $\sigma_{obs} < 3.9\sigma_{SM}$ at 95% CL.

5. $ZW + ZZ \to \ell\ell$ +jets

A search for ZW and ZZ Production in leptons+ jets final state is also carried out. This channel is dominated by Z+jets production. A Jet likelihood ratio is formed to discriminate between jets coming from quarks and jets coming from gluons. Based on the events that pass a cut imposed on the likelihood ratio a NN is formed and fitted to a linear combination of the backgrounds. Based on 4.8 fb^{-1} we set an upper limit on the cross section $\sigma_{ZW+ZZ} < 22$ pb where the theoretical prediction is 7.5 pb.

6. Conclusion

The recent results in diboson production at the Tevatron, using 3.6 - 6.0 fb^{-1} of data, have been presented in both leptonic and semi-leptonic final states. Measured cross section and TGCs for these processes are in agreement with the SM predictions. CDF is now observing processes with cross sections less than a factor 10 larger than the SM Higgs cross section, and on the way of studying the diboson production with *b* jets in the final state.

References

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