PROCEEDINGS OF SCIENCE

Measurement of the diboson production in p anti-p collisions at √s=1.96 TeV

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The Tevatron allowed for the first time to observe diboson production at a hadron collider. WW, WZ and ZZ production are rare processes with cross-section predictions in the Standard Model below 10 pb. Deviations from this expected values arise from triple gauge couplings or new physics phenomena. Besides the measurements of dibosons production cross-sections are an important benchmark towards the observation of the Higgs boson. Recent results on Wγ, WZ and ZZ production from the D0 collaboration are presented.

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[1] Speaker

1. Diboson production and Triple Gauge Couplings

The measurement of diboson production cross-sections is a test of the SM, which allows to compute precisly the predicted values. Deviations from the standard model can occur through an enhancement of triple gauge couplings or production of heavy resnonances decaying into boson pairs. As the Higgs boson can also decay into WW and ZZ final states, the measurement of diboson production is an important benchmark measurement for Higgs searches and constitutes an irreducable background to Higgs production.

Diboson final states can be produced at the Tevatron in the t-, u- or s-channel (see figure 1), with the s-channel mode being senstive to triple gauge couplings. Charged triple gauge couplings occur in the standard model, even though anomolous contributions occur in some models for new physics for the $W\gamma$ ($WW\gamma$ coupling), WZ (WWZ coupling) and WW ($WW\gamma$ and WWZ coupling) final states, where the $W\gamma$ and WZ final states being only produced at hadron colliders. Neutral triple gauge couplings can be measured from $Z\gamma$ ($Z\gamma\gamma$ and $ZZ\gamma$ coupling) and ZZ ($ZZ\gamma$ and ZZZ) final states and are not present in the standard model.

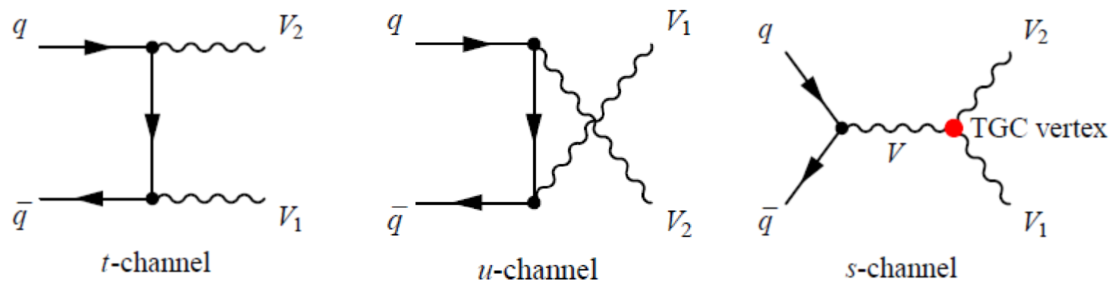

Figure 1: First order Feynman diagrams for diboson production.

The lagrangian of the charged triple gauge coupling vertex can be expressed with g_1^γ, the minimal coupling term from the electromagnetic gauge invariance which is equal to 1, and five free parameters: κ_γ, the anomalous magnetic momentum of the W, Λ_γ related to the magnetic and electric quadrupole momenta of the W, completed by g_1^Z and Λ_Z.. In the standard model κ_i and g_1^i are equal to 1, and Λ_i equal to 0. In order to search for new physics beyond the standard model, two common paramterisations are used in the following. The SU(2)×U(1) parameterisation is related to unitarity constraints at the tree level and reduces the set of free parameters to three [2], Λ_Z, Δg_1^Z and $\Delta\kappa_Z$, with the relation $\Delta\kappa_Z=\Delta g_1^Z-\Delta\kappa_\gamma \tan^2\theta_W$ and $\Lambda_\gamma=\Lambda_Z$. The HISZ parametrisations assumes an equal coupling between SU(2)×U(1) and the Higgs field and has only two free parameters Λ_Z and $\Delta\kappa_Z$ with the relation $\Delta\kappa_Z=\Delta g_1^Z(\cos^2\theta_W\ ^{-}\sin^2\theta_W)$. In the case of non-standard model values, gauge boson production at high energies must conserve unitarity. Therefore the results presente herewithin use a dipole form scale factor Λ in the description of the couplings $\alpha(\text{s-hat}) \rightarrow \alpha_0/(1+\ \text{s-hat}/\Lambda^2)^2$, where s-hat is the square of the partonic centre-of-mass energy and α_0 is the coupling value of $\Delta\kappa_i$, Λ_i in the low energy approximation. This same prescription has been used at LEP, but is not used by the LHC collaborations.

[2] In the following $\Delta x = x-1$, with x being either g_1^i or Λ_i.

2. Wγ production

The Wγ final state has been studied at D0 in the $W\gamma \rightarrow \mu\nu\gamma$ channel which is less sensitive to effects of bremsstrahlung than the corresponding electron channel. The Wγ final state is particularly sensitive to technicolor models where spin 1 technicolor resonnaces $\rho_T^{\pm}$ or $a_T^{\pm}$ decay to $W^{\pm}\gamma$. Wγ final states can also be produced in models of general gauge mediated symetry breaking.

The presented D0 analysis [1] is based on a dataset with a luminosity of 4.2 fb^{-1} where a total of 492 events have been selected. The number of backgrounds events is estimates to be 134.2, mostly due to γ misidentification and W+jets events. From the estimated 375.6 signal events a total cross-section of 15.2±0.4(stat)±1.6(syst) pb has been measured for the Wγ+X process. This measurement can be compared to the expected cross section using the CTEQ6L1 parton density function parametrisation of 16.0±0.4 pb. No deviation is observed.

Figure 2 (right) shows the distribution of the charged signed rapidity difference between the outgoing lepton from the W decay and the photon. In the standard model, due to a destructive interference between tree level diagrams, a radiation amplitude zero can be observed as a dip in the distribution (red line) around -0.3 This dip does not occur for models where anomolous couplings are present. As a unique test of the standard model, no deviation from its prediction is seen in the data.

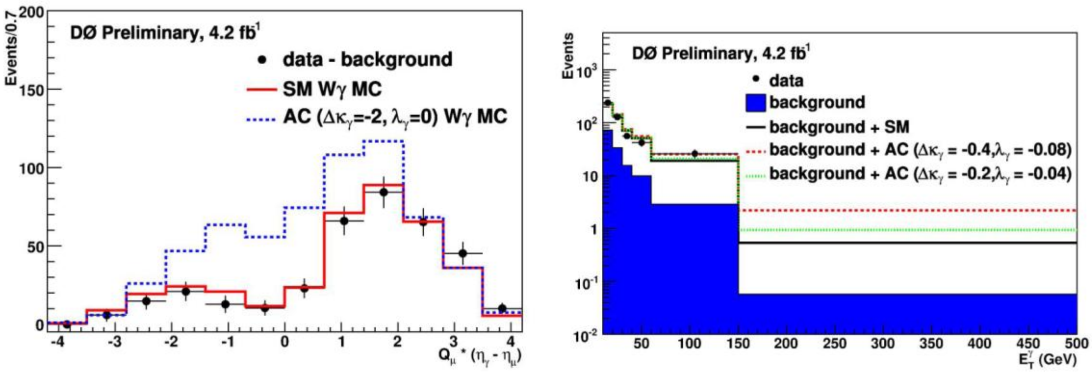

Figure 2 : Charged-signed rapidity difference between the outgoing lepton and photon (left) and transverse Energy distribution of the photon (right).

The triple gauge coupling parameters are extracted from fits to the transverse energy distribution of the photon shown in figure 2 (left). At the 68% confidence level, the obtained range of possible values from the one dimensional fit are $-0.07<\Delta\kappa_\gamma<0.07$ and $-0.012<\Lambda_\gamma<0.011$, both compatible with zero. The limits obtained from the LEP2 combined analysis are $-0.072 <\Delta\kappa_\gamma<0.017$ and $-0.049<\Lambda_\gamma<0.008$. With this presented measurement D0 has achieved at a hadron collider a sensitivity similar to the one obtained at LEP.

3.WZ production

The selection of WZ events is based on the signature of three leptons, electrons or muons, leading to 4 different final states (eeμ, μμe, eee and μμμ). The leptons of the same type are required to be of opposite charge, since coming from the Z-decay. From studies of Monte-Carlo events, the assignment of the leptons to the Z and W decays have been verified to match 100% for the mixed channels and to be of the order of 90% when the three leptons are of the same type. Figure 3 shows the transverse mass of the reconstructed W boson and the reconstructed Z mass.

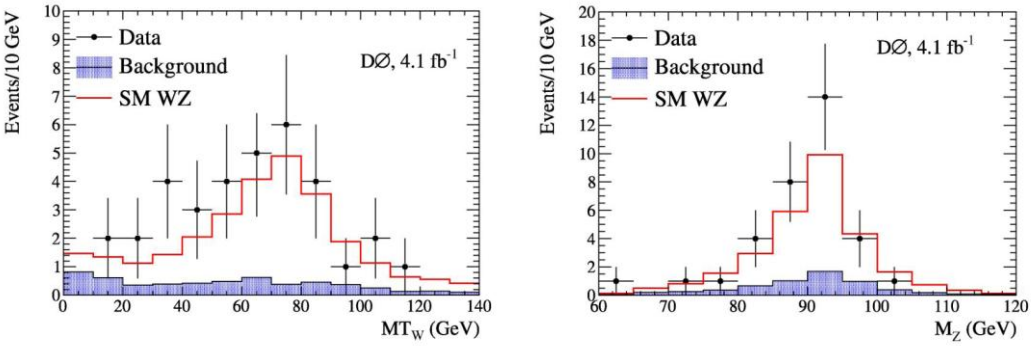

Figure 3 Transvers W-mass distribution and Z-mass distribution reconstructed in the selected WZ events.

On a dataset corresponding to a luminosity of $4.1 fb^{-1}$, 34 events have been observed with 6 estimated background events mainly due to the misidentification of the W boson. This leads to a cross section measurement of $3.9^{+1.01}_{-0.85}$ (stat+syst) pb. The obtained value can be compared to the calculation of the cross-section at NLO, which is expected to be at 3.25±0.19 pb and in good agreement with the measured value. Possible deviations could again occur from the decay of technicolor $\rho_T^{\pm}$ particle into $W^{\pm}Z$ or from supersymetric charginos and neutralinos decays.

The limits on WWZ couplings have been extracted from the transverse momentum distribution of the Z, shown in figure 4. The limits obtained in the SU(2)×U(1) parametrisation are $-0.075<\Lambda_Z<0.093$, $-0.053 < \Delta g_1^{\ Z} < 0.156$ and $-0.376 < \Delta\kappa_Z < 0.686$, fitting always one parameter and keeping the other two parameters at 0. For the HISZ parametrisation the allow range for $\Delta\kappa_Z$ obtained lays between 0.027 and 0.080 for $\Lambda_Z=0$, for Λ_Z between -0.075 and 0.093 for $\Delta\kappa_Z=0$. This limits are the most stringent limits from the direct study of WZ production.

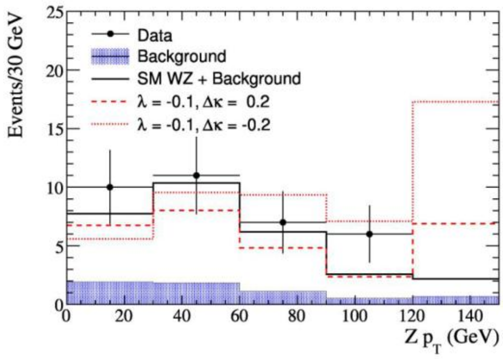

Figure 4 Transverse momentum distribution of the reconstructed Z-boson compared to different predictions of anomalous triple gauge couplings.

4. ZZ production

ZZ production has the smallest cross-section of all the diboson processes but with two pairs of opposite sign leptons this channel has a very clean signature. A first observation has been made in 2008 with 3 four lepton events. With a luminosity of $6.4 fb^{-1}$, 10 events have been observed in the four lepton channel, with 2 events in the 4 electron channel, 4 events in the 4 muon channel and 3 events in the 2μ2e channel. Figure 5 (left) shows the distribution of these events in the plane of the two reconstructed Z masses. No particular sign of a resonant production can be seen in the distribution of the four-lepton invariant mass (figure 5 middle) and the p_T spectrum of the Z bosons is well described by the simulation.

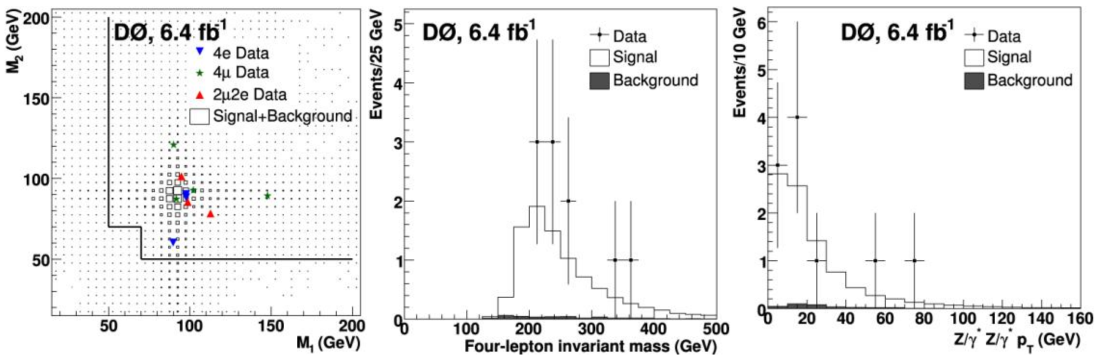

Figure 5: Distribution of the reconstructed Z-masses (left), four lepton invariant mass distribution (middle) and distribution transverse momentum of the Z bosons (right).

The ZZ cross-section derived from this event selection is $1.26^{+0.47}$-0.37 (stat)±0.11(syst) pb, applying a correction factor of 0.93 for the photon contribution. A previous measurement has been made in the two lepton, two neutrino channel with 2.7fb^{-1} which can be combined with this measurement to obtain a cross-section of $1.40^{+0.43}_{-0.37}$ (stat) ± 0.14 (syst) pb. The standard model expectation at NLO is 1.3±0.1 pb, in good agreement with the measurement.

The ZZ channel is also a decay channel of the Higgs boson, and studies have shown, that the angular distribution between the two decay planes of the Z boson (figure 6 left) are sensitive to different types of Higgs bosons. Figure 6 (middle) shows the distribution of this variable for a Higgs-like scalar (green), a heavy scalar (red) and an CP-odd scalar (red) for a mass of 200 GeV. The distribution of this variable for the events selected by D0 is displayed in figure 6 (right) with no particular structure to be distinguished as the low statistics of events shows no Higgs signal.

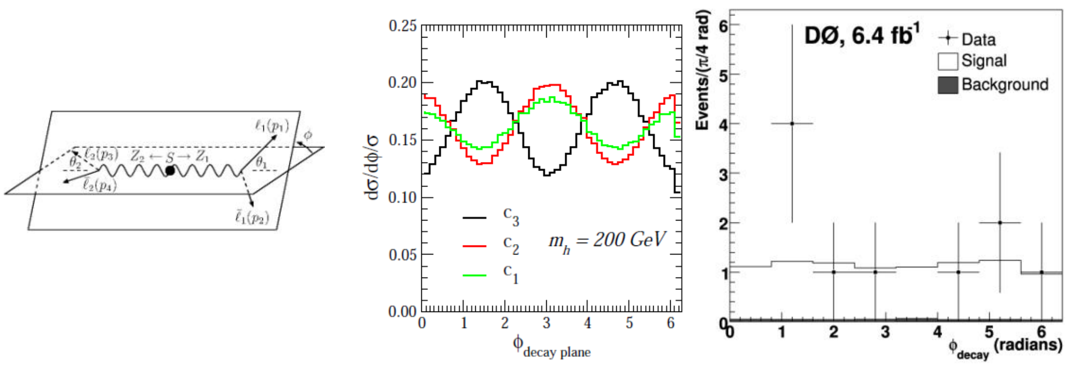

Figure 6: Definition of the decay plan angle (left), predictions for differrent different Higgs models (middle) and D0 measurement (right).

5. Summary

The Tevatron has allowed measuring the cross-sections of all diboson processes at a hadron collider with an integrated luminosity of 4 to 6 fb^{-1}. The summary of the measurements by the D0 and CDF collaboration are shown in figure 7, together with the measurement of the top pair and single top production. The predictions from the standard model for all the measured cross-sections are in agreement with the standard model and no significant deviations have been observed. Limits on the parameters of triple gauge couplings have been derived and no sign of an anomalous coupling has been seen within the achieved precision, some of the limits being the tightest limits obtained up to now. With the luminosity accumulated during the entire Tevatron running, an increase by a factor two in statistics can be expected, leading to an improvement of both the statistical and the systematic error and leading to a legacy measurement of these cross-section at √s=1.96 TeV to be compared with the results of the LHC at 7 and 14 TeV.

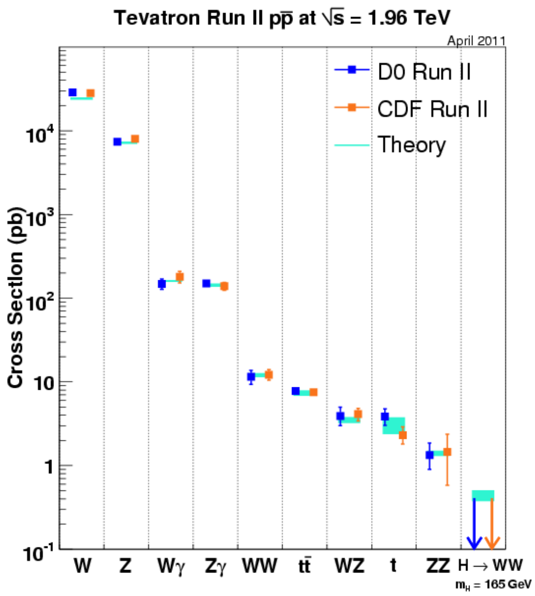

Figure 7 : Summary of diboson cross-section measurements at the Tevatron.

References

[1] D0 Collaboration, *Wγ production at D0 withL= 4.2 fb⁻¹data* , D0 Note 6172-CONF, March 2011. See also: V.M. Abazov et al., *Wγ Production and Limits on Anomalous WWγ Couplings in ppbar Collisions at √s = 1.96 TeV. Accepted Phys.Rev. Lett. November 2011.*

[2] V.M Abazov et al., D0 Collab., *Measurement of the WZ→lνll cross section and limits on the anomalous triple gauge couplings in ppbar collisions at √s=1.96 TeV*, Phys. Lett B 695 (2011) 67.

[3] V.M Abazov et al., D0 Collab., *Measurement of the ZZ production cross section and limit in ppbar collisions at √s=1.96 TeV*, Phys. Rev. D 84 (2011) 011103.