International Journal of Modern Physics A

DI-BOSON PHYSICS AT THE TEVATRON

Yurii Y. Maravin for the CDF and DØ Collaborations

Fermi National Accelerator Laboratory
M.S. 357, P.O. Box 500
Batavia, IL 60563, USA.
email: maravin@fnal.gov

Using almost twice the luminosity of Run I, we present preliminary results on di-boson final states production at the Tevatron. These results include cross section measurements of most di-boson final states including the first measurement of WW cross section.

Keywords: di-boson physics, tevatron, CDF, DØ

1. Introduction

The Standard Model (SM) of electroweak interactions is described by the non-Abelian gauge group $SU(2)_L \times U(1)_Y$. Measurements of gauge boson pair-production offer a good opportunity to test the non-Abelian structure of the SM. Furthermore, these measurements are sensitive to new physics, because anomalous trilinear couplings [1] or the production and decay of new particles would enhance the rate of the di-boson pair-production. The higher Run II Tevatron center of mass energy of 1.96 TeV and about twice the luminosity of Run I increases the sensitivity to new phenomena. Significant improvements of the CDF and DØ detectors [2,3] in Run II permits us to fully utilize unique opportunities of studying the di-boson final states at the energy frontier of particle physics.

The preliminary cross section measurements and limits on di-boson production presented in this paper are an initial step in the Run II program of a detailed experimental survey of vector boson pair-production at the Tevatron.

2. Study of $W\gamma$ and $Z\gamma$ production

Both experiments study W and Z with photon production using leptonic decays of W and Z. We reconstruct leptons using the standard selection criteria developed for analysis of inclusive boson production at the Tevatron. The photon candidate is required to be separated from leptons from W or Z decay by $\Delta R \equiv \sqrt{\Delta\phi^2 + \Delta\eta^2} > 0.7$, where $\Delta\phi$ and $\Delta\eta$ are separation in azimuth angle and pseudorapidity between a photon and a lepton, respectively. This requirement is made to reduce contribution from bremssrahlung photon production ($\ell\ell \to \ell\ell\gamma$). We also require transverse energy E_T of a photon candidate to exceed 7 GeV for

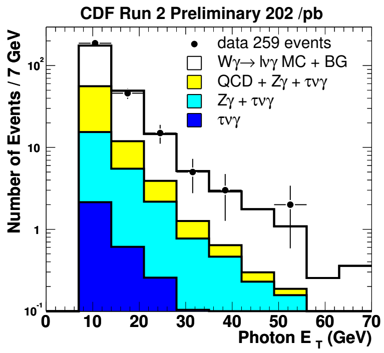

Fig. 1. The photon E_T distribution for $W\gamma$ candidate and background events (CDF).

CDF and 8 GeV for DØ analyses. The studies are done on the data set that corresponds to roughly 200 pb^{-1} of integrated luminosity.

The dominant background to the $W\gamma(Z\gamma)$ production is from $W+jet(Z+jet)$ processes, where a jet is misidentified as a photon. This background is estimated by measuring the rate at which a jet is misidentified as a photon in a data sample of QCD multi-jet events. The measured misidentification rate is then applied to the $W+jet$ and $Z+jet$ data samples to estimate the QCD background to the $W\gamma$ and $Z\gamma$ processes, respectively. Other backgrounds are studied in detail and found to be negligible. In the $W\gamma$ process CDF observed 259 candidate events of which 75.1 ± 15.0 are expected from QCD background, while DØ observed 223 candidate events with estimated background of 124.1 ± 12.5 events. In the $Z\gamma$ analysis, CDF identified 69 candidate events with 4.4 ± 1.3 background events, and DØ observed 101 candidates of which 14.8 ± 1.5 are expected from QCD background processes.

We measure the $W\gamma$ cross section to be $19.7 \pm 2.8(\mathrm{stat}+\mathrm{syst}) \pm 1.1(\mathrm{lumi})$ pb (CDF) and $19.3 \pm 6.7(\mathrm{stat}+\mathrm{syst}) \pm 1.2(\mathrm{lumi})$ pb (DØ). This agrees well with the theory prediction of 19.3 and 16.4 pb, respectively. [a] The cross section of the $Z\gamma$ production is measured at CDF to be $5.3 \pm 0.7(\mathrm{stat}+\mathrm{syst}) \pm 0.3(\mathrm{lumi})$ pb and that at DØ to be $3.9 \pm 0.5(\mathrm{stat}+\mathrm{syst}) \pm 0.3(\mathrm{lumi})$ pb. These measurements also agree with the theory prediction of 5.4 pb and 4.3 pb, respectively.

Most new phenomena effects predict enhancement in both the cross section and the number of high-E_T photons. We plot photon E_T distributions for $W\gamma$ and $Z\gamma$ processes in Figs. 1-4. We observe no deviation from the SM in the photon E_T distributions.

[a]The differences between CDF and DØ $W\gamma$ and $Z\gamma$ theory cross sections is due to a different threshold on the photon E_T.

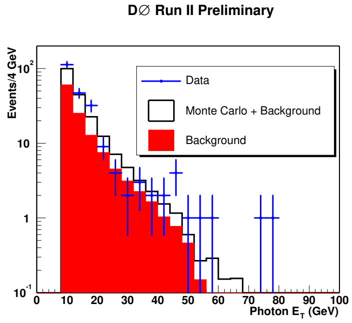

Fig. 2. The photon E_T distribution for $W\gamma$ candidate and background events (DØ).

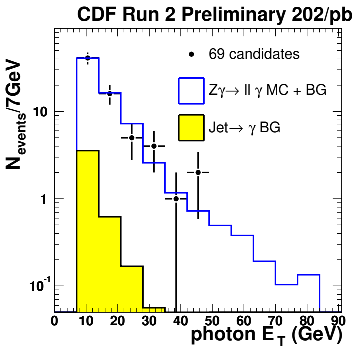

Fig. 3. The photon E_T distribution for $Z\gamma$ candidate and background events (CDF).

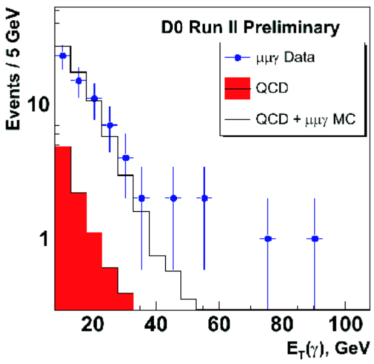

Fig. 4. The photon E_T distribution for $Z\gamma$ candidate and background events (DØ).

3. Study of WW production

Both experiments study WW production in the di-lepton final state using data set corresponding to about 200 pb^{-1} and 250 pb^{-1} of integrated luminosity for CDF and DØ, respectively. In the channel where both W bosons decay into electrons or muons, the dominant background is from $Z \to \ell\ell$ decays. Other background processes to W-pair production include $W + jet$ process and $t\bar{t}$ production. CDF observed 17 WW candidate events with 4.8 ± 0.7 estimated background events. DØ observed 25 candidate events in which 8.1 ± 0.7 are calculated to be from background processes.

The measured cross sections are $14.3^{+5.6}_{-4.9}$(stat) $\pm$ 1.6(syst) $\pm$ 0.9(lumi) pb and $13.8^{+4.3}_{-3.8}$(stat) $\pm$ 1.0(syst) $\pm$ 0.9(lumi) pb for CDF and DØ analyses, respectively. These numbers are in a good agreement with theory prediction of 13.5 pb. Thus, we observed no enhancement of WW production that could be produced by either anomalous WWZ or $WW\gamma$ couplings or by a new particle (such as Higgs).

4. Study of WZ and ZZ production

CDF searches for evidence of WZ and ZZ processes by selecting events with two leptons consistent with being produced by Z decay and either of three following options:

- a large missing E_T from $Z \to \nu\nu$ or $W \to \ell\nu$ where lepton is undetected,
- a third lepton and a missing E_T from $W \to \ell\nu$,
- two more leptons from $Z \to \ell\ell$ decay.

We expect to observe 2.72 ± 0.33 signal events with estimated background of 2.29 ± 0.42 events. We observe 4 candidate events that falls into the first category (large missing E_T). The 95% C.L. upper-limit on the combined cross section of WZ and ZZ is set to be 13.9 pb. The standard model expectation is 5.2 ± 0.4 pb.

The search for WZ production in DØ is done by selecting events with three leptons (electrons and/or muons) that are consistent with by WZ production in data sample that corresponds to about 200 pb^{-1} of integrated luminosity. We expect to observe 1.02 ± 0.07 signal events with estimated background of 0.39 ± 0.02 events. We find 1 candidate event with three muons in the final state. The corresponding 95% C.L. upper limit on the WZ cross section is measured to be 15.1 pb. The theory prediction of the cross section is 3.7 pb.

5. Summary

Presented results of di-boson studies at the Tevatron are in a good agreement with the SM predictions. We summarize preliminary values of the measured di-boson cross sections and single boson production cross sections in Fig. 5. Detailed studies of di-boson production on the currently available data sample [b] will include search for anomalous trilinear couplings. These studies are expected to be submitted for publications soon.

[b] Current data sample available for analysis corresponds to almost double integrated luminosity than that used in the presented analyses.

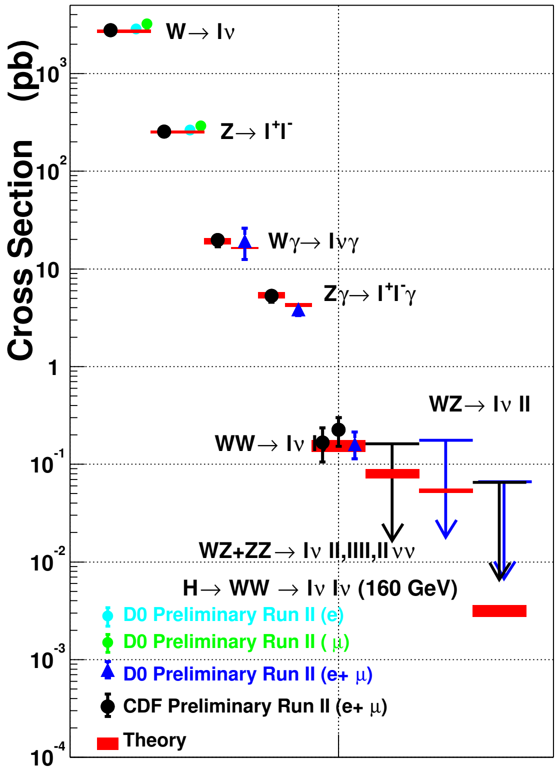

Fig. 5. A product of cross section and branching fraction for some single and pair di-boson processes measured in CDF and DØ at Run I and Run II.

Acknowledgments

We thank the staffs at Fermilab and collaborating institutions and funding agencies providing support to the CDF and DØ collaborations.

References

References

1. U. Baur and E. L. Berger, Phys. Rev. D **41**, 1476 (1990);
   K. Hagiwara, J. Woodside, and D. Zeppenfeld, Phys. Rev. D **41**, 2113 (1990).
2. A. Sill *et al.*, Nucl. Instrum. Meth. A **447**, 1 (2000).
3. T. LeCompte and H. T. Diehl, Ann. Rev. Nucl. Part. Sci. **50**, 71 (2000).