W/Z+Jets and W/Z+HF Production at the Tevatron

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On behalf of the CDF and DO Collaborations.

The CDF and D0 collaborations performed a comprehensive study of the production of vector bosons, W and Z, in association with energetic jets. Understanding the W/Z + jets and W/Z + c, b-jets processes is of paramount importance for the top quark physics, for the Higgs boson measurements, and for many new physics searches. In this contribution the most recent measurements of the associated production of jets and vector bosons in Run II at the Tevatron are presented. The measurements are compared to different perturbative QCD predictions and to several Monte Carlo generators.

1 Introduction

The study of the production of electroweak bosons in association with jets of hadrons constitutes a fundamental item in the high-p_T physics program at the Tevatron. Vector bosons plus jets final states are a major background to many interesting physics processes like single and pair top quarks production, Higgs, and super-symmetry. Precise measurements of W/Z + jets production provide a stringent test of perturbative QCD predictions [1–5] at high Q^2, and offer the possibility to validate Monte Carlo simulation tools [6–11]. The latest vector boson plus jets results at the Tevatron are reviewed and discussed.

2 W/Z + jets measurements

The CDF experiment recently measured Z + jets production cross sections with the full Tevatron run II dataset, corresponding to 9.64 fb^{-1} of integrated luminosity [12]. Differential cross sections as a function of several variables have been measured, including jet p_T, jet rapidity and jet multiplicity, angular variables like di-jet $\Delta\phi$ and Δy, and $H_T^{\text{jet}} = \sum p_T^{\text{jet}}$. Events are required to have two electrons or muons with a reconstructed invariant mass in the range $66 \leqslant M_Z \leqslant 116$ GeV/c^2 around the Z boson mass. Jets are clustered with the Midpoint algorithm [13] in a cone radius of 0.7, and are required to have $p_T \geqslant 30$ GeV/c and $|y| \leqslant 2.1$. The background estimation is performed both with data-driven and Monte Carlo techniques, the QCD and W+jet

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backgrounds are estimated from data, other backgrounds contributions like $t\bar{t}$, diboson and $Z/\gamma^* \to \tau^+\tau^-$ are estimated from Monte Carlo simulation. The cross sections are unfolded back to the particle level accounting for acceptance and smearing effects employing ALPGEN+PYTHIA Monte Carlo. The measured cross sections are compared to predictions from the Monte Carlo event generators ALPGEN+PYTHIA [6], POWHEG+PYTHIA [7], and to the fixed order perturbative QCD predictions MCFM [2], BLACKHAT+SHERPA [3], LOOPSIM+MCFM [4] and to a fixed order prediction including NLO EW corrections [5]. Fixed order predictions include parton-to-particle correction factors that account for the non-perturbative underlying event and fragmentation effects, estimated with ALPGEN+PYTHIA Monte Carlo simulation. Figure 1 shows the measured cross section as a function of $H_T^{\rm jet}$ in $Z/\gamma^* + \geqslant 1$ jet events.

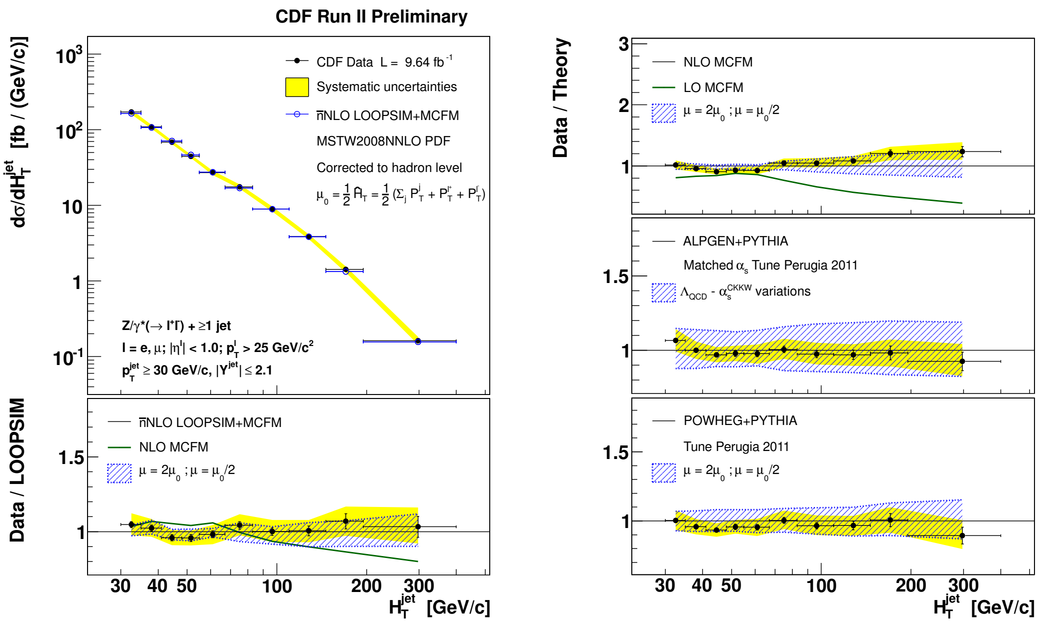

Figure 1: Measured differential cross sections as a function of $H_T^{\rm jet}$ in $Z/\gamma^* + \geqslant 1$ jet events. Data (black dots) are compared to LOOPSIM prediction (open circles). The shaded bands show the total systematic uncertainty, except for the 5.8% luminosity uncertainty, the blue area represents simultaneous variation of renormalization and factorization scales.

A new measurement of $W \to e\nu$ + jets production cross section has been performed with the D0 experiment with 3.7 fb^{-1} of integrated luminosity [14], including a comprehensive study of several kinematics variables. Events are selected with a reconstructed electron of $p_T \geqslant 15$ GeV/c and $|\eta| \leqslant 1.1$, the transverse mass of the W, reconstructed with the electron and $\not{E}_T$, is required to be $M_T^W \geqslant 40$ GeV/c^2, jets are reconstructed with the Midpoint algorithm in a radius $R = 0.5$ and required to have $p_T \geqslant 20$ GeV/c and $|y| \leqslant 3.2$. Data are compared to several Monte Carlo generators, ALPGEN+PYTHIA, ALPGEN+HERWIG [6], PYTHIA [8], HERWIG [9] and SHERPA [10], to perturbative NLO QCD predictions from BLACKHAT+SHERPA [3], and to the all order resummed prediction HEJ [11]. Figure 2 shows the average number of jets and the probability of third jet emission as a function of the Δy between the most rapidity-separated jets, in events with $W \to e\nu + \geqslant 2$ jets.

3 W/Z + heavy flavor jets production

The measurement of vector boson production with associated heavy flavor jets provides an important test of perturbative QCD predictions, and can be used to improve the determination

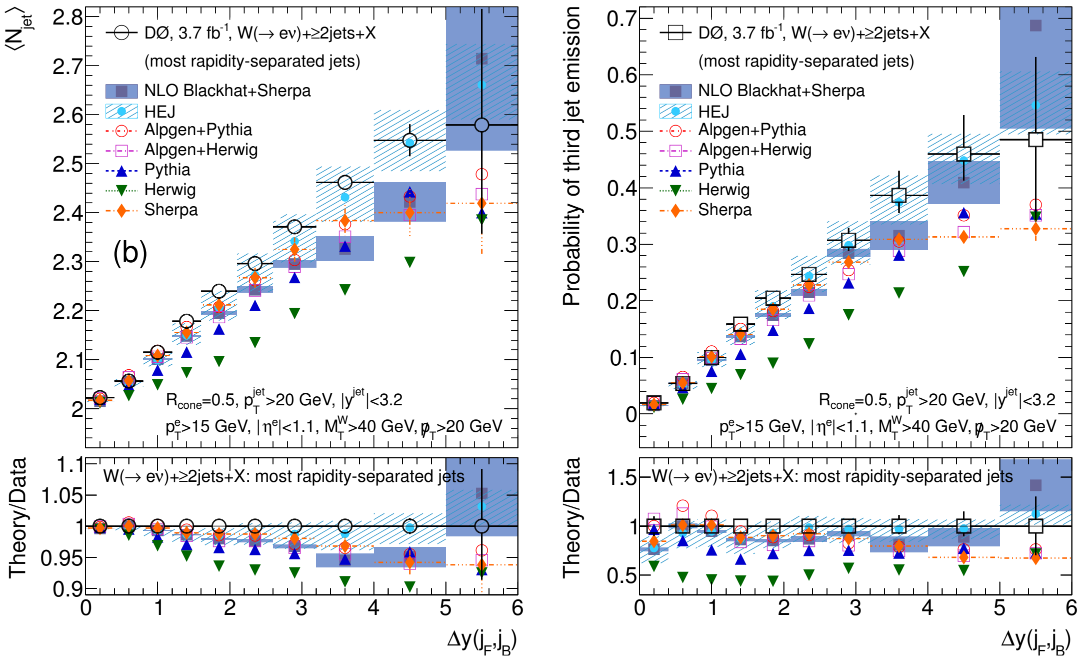

Figure 2: Measured average number of jets (left) and probability of third jet emission (right) as a function of the Δy between the most rapidity-separated jets, in events with $W \rightarrow e\nu + \geqslant 2$ jets. Data (open black dots) are compared to several Monte Carlo generators and predictions. The lower pane shows the theory/data ratio.

of PDF. Understanding these processes is also critical for the measurement of Higgs boson production in association with a W or Z and in the search for SUSY.

The W + charm production cross section has been measured by CDF with 4.3 fb^{-1} of integrated luminosity [15]. Charm jets are identified with an algorithm which identifies soft leptons coming from the semileptonic decay of the charm. The measurement exploits the charge correlation between the soft lepton and the lepton coming from the leptonic decay of the W to reduce the background contamination. The measured cross section of $13.6 \pm 2.2(\mathrm{stat})^{+2.3}_{-1.9}(\mathrm{syst}) \pm 1.1(\mathrm{lum})$ pb is in good agreement with the NLO prediction of 11.4 ± 1.3 pb from MCFM.

The W + b-jet cross section has been measured by D0 with 6 fb^{-1} of integrated luminosity [16]. $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ decay channels are combined, and a multivariate technique is used to identify b-jets. The measured cross section of 1.05 ± 0.12 pb is in good agreement with the perturbative QCD NLO prediction from MCFM of $1.34^{+0.41}_{-0.34}$ pb, and consistent with predictions from the Monte Carlo generators SHERPA (1.08 pb) and MADGRAPH (1.44 pb).

The CDF and D0 collaborations recently measured differential cross sections of Z + b-jet production with the full Tevatron run II dataset [17, 18], with integrated luminosities corresponding to 9.7 fb^{-1} and 9.13 fb^{-1} respectively. Figure 3 shows the measured cross sections unfolded to particle level and compared to NLO perturbative QCD predictions from MCFM and Monte Carlo generators SHERPA and ALPGEN+PYTHIA. The measured cross sections are in reasonable agreement with theory, within large experimental and theoretical uncertainties.

Summary

W/Z + jets and W/Z + heavy flavor measurements belong to the Tevatron legacy. All the measurements are in general good agreement with the perturbative NLO QCD predictions, in the tail of some distributions like H_T^{jet} and di-jet Δy the inclusion of higher order corrections improves the agreement between data and theory. Detailed studies of differential distributions in W/Z + jets and W/Z + heavy flavour production provide an important test of the different Monte Carlo generators and theoretical predictions, and a fundamental validation of the background

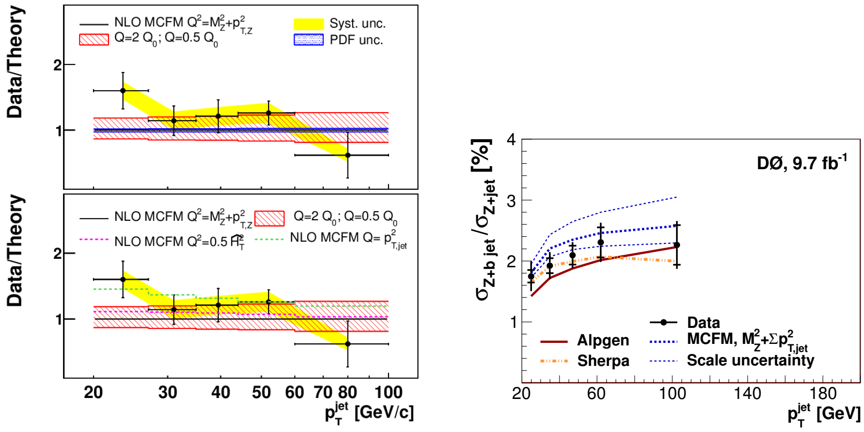

Figure 3: Measured Z + b-jet differential cross sections as a function of b-jet p_T with the CDF (left) and D0 (right) detectors. Data (black dots) are compared to MCFM NLO prediction and Monte Carlo generators.

modeling of such processes in the search for new physics.

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