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W/Z+Jets Results from CDF

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The CDF Collaboration has a comprehensive program of studying the production of vector bosons, W and Z, in association with energetic jets. Excellent understanding of the standard model W/Z+jets and W/Z+c,b-jets processes is of paramount importance for the top quark physics and for the Higgs boson and many new physics searches. We review the latest CDF results on Z-boson production in association with inclusive and b-quark jets, study of the p_T balance in Z+jet events, and a measurement of the W+charm production cross section. The results are based on $4-5\ fb^{-1}$ of data and compared to various Monte Carlo and next-to-leading order perturbative QCD predictions.

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1. Introduction

The study of the production of electroweak bosons in asociation with jets of hadrons constitutes a fundamental item in the high-p_T physics program at CDF. Vector bosons plus jets final states are a major background to many interesting physics processes like single and pair top quarks production, SM Higgs, and supersymmetry. Precise measurements of W/Z + jets production provide a stringent test of pQCD predictions at high Q^2[1], and offer the possibility to validate Monte Carlo simulation tools[2]. The latest vector boson plus jets results at CDF are reviewed and discussed in comparison with previous measurements. A new result on Z-boson production in association with inclusive jets[3], a measurement of the W+charm production cross section[4] and a study of the p_T balance in Z+jet events[5] are presented.

2. $Z/\gamma^* \to \mu^+\mu^-$ + jets

The Z-boson plus jets production when the Z decays in an electron-positron pair was already measured at CDF and published in [6]. The new measurement in the $Z/\gamma^* \to \mu^+\mu^-$ channel, based on 6 fb^{-1} of data, is complementary to the electron channel and therefore defined in the same kinematic region. The two muons are required to have $p_T \geqslant 25$ GeV/c and pseudorapidity $|\eta| \leqslant 1.0$, the invariant mass of the reconstructed Z-boson has to be in the range $66 \leqslant M_Z \leqslant 116$ GeV/c^2. Jets are reconstructed with the midpoint algorithm[7] in a cone of $R = 0.7$, and required to have $p_T \geqslant 30$ GeV/c and rapidity $|Y| \leqslant 2.1$. Background estimation is done both with Monte Carlo and data-driven techniques. The contribution coming from QCD dijet, W+jets and decayed in flight particles is estimated from data, other contributions coming from WW, WZ, ZZ, $Z/\gamma^* + \gamma$ and $t\bar{t}$ events are computed using MC samples. The measured cross sections are corrected back to hadron level and compared to next-to-leading order (NLO) pQCD predictions including non-perturbative contributions. The main systematic uncertainty of the measurement is due to the jet energy scale which contributes between $3-15\%$. Other considered sources of systematic uncertainty are the background subtraction, the trigger and muon identification efficiencies and the additional energy flow coming form multiple $p\bar{p}$ interaction. The NLO prediction are computed using the MCFM program [2], the CTEQ6.1M PDFs[8] are employed and the renormalization and factorization scales are set to $\mu_0^2 = \mathrm{M_Z^2} + \mathrm{p_T^2(Z)}$. Data are well described by the theoretical predictions and good agreement is observed in all the distributions. Measured cross sections as a function of inclusive jet p_T and jet multiplicity are shown in figure 1.

3. W + charm

An uncertainty of $\sim 30\%$ affects the theoretical expectation of W + charm production, mainly due to a lack of constraints on the shape of the s-quark PDF at Q^2 of the order of M_W^2 [9] and to the dependence on the factorization and renormalization scales [10]. In this context, the measurement of the associated production of W bosons with single charm at the Tevatron is an opportunity to set an experimental constraint to the theory. The new result on the W + charm production cross section uses the semileptonic electron decay of the charm, and is based on 4.3 fb^{-1} of data collected at the CDF detector. Charm hadrons are identified looking for an electron inside the jet, figure 2

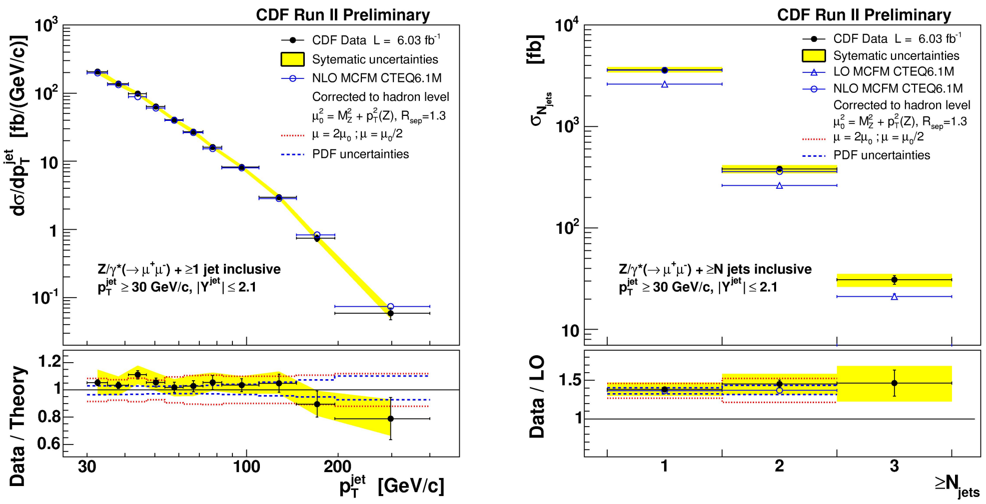

Figure 1: Measured inclusive jet differential cross sections as a function of p_T^{jet} in $Z/\gamma^* + \geqslant 1$ jet events and as a function of jet multiplicity. Data (black dots) are compared to NLO pQCD predictions (open circles). The shaded bands show the total systematic uncertainty, except for the 5.8% luminosity uncertainty. The dashed and dotted lines indicate the PDF uncertainty and the variation with μ_0 of the NLO pQCD predictions, respectively.

shows the p_T of electrons associated to charm jets in W + charm events. The measurement exploits the charge correlation between the W boson and the electron from the semileptonic decay of the charm hadron. Charge conservation in the process $gq \rightarrow Wc(q = d, s)$ allows as final states only the pairings $W^+\bar{c}$ and W^-c. It follows that the charge of the electron from the semileptonic decay and the charge of the lepton from the W decay are always of opposite sign, and the excess of opposite-sign events with respect to same-sign events can be used to measure the W + charm production cross section. Jets are clustered with the standard cone algorithm in a cone of $R = 0.4$ and the measurement is limited to the kinematic region $p_{Tc} > 20\ GeV/c$ and $|\eta_c| < 1.5$. The measured value of $\sigma_{W+c} \times BR(W \rightarrow l\nu) = 21.1 \pm 7.1(\text{stat}) \pm 4.6(\text{syst})\ pb$ is in agreement with the NLO theoretical prediction $11.0^{+1.4}_{-3.0}\ pb$ calculated with MCFM [11]. A previous measurement of W + charm production at CDF was performed using the semileptonic muon decay of the charm[11], the measured cross section is $\sigma_{W+c} \times BR(W \rightarrow l\nu) = 9.8 \pm 2.8(\text{stat})^{+1.4}_{-1.6}(\text{syst}) \pm 0.6(\text{lum})$ pb. Since the two measurements are defined in the same kinematic region the results can be compared directly one to each other and to the same NLO theoretical prediction.

4. Z + jet p_T balance

The large Z + jets sample collected at the CDF detector can be used for jets studies. New results based on 4.6 fb^{-1} employ the Z + jet sample to understand the quark-gluon composition, to check the QCD jet modeling of Monte Carlo simulation and to study the possibility of reducing the uncertainty on the jet energy scale of hadronic jets. The p_T balance observable is defined as the average of the ratio between the p_T of the jet anf the p_T of the Z Boson in events with a single

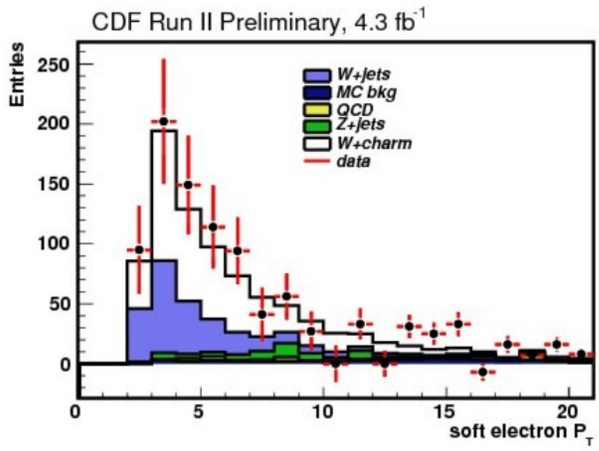

Figure 2: p_T spectrum of the soft electrons associated to charm jets in W + charm events.

jet back-to-back with respect to a Z Boson. The mismodeling of large angle final state radiation is found to be the main source of uncertainty in setting the jet energy scale [5].

5. Conclusions

New results on Z + jets and W + charm at CDF are in good agreement with NLO pQCD calculation. In both measurements the combination of muon and electron decay channels will provide more precise measurements to constrain the theoretical predictions and to reduce the uncertainties on the background estimation for new physics searches.

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