Measurement of Inclusive Jet Cross Sections in $Z/\gamma^* \to e^+ e^-$+jets Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV

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Inclusive jet cross sections in $Z/\gamma^*$ events, with $Z/\gamma^*$ decaying into an electron-positron pair, are measured as a function of jet transverse momentum and jet multiplicity in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV with the upgraded Collider Detector at Fermilab in Run II, based on an integrated luminosity of 2.5 fb$^{-1}$. The measurements cover the rapidity region $|y^{\text{jet}}| < 2.1$ and the transverse momentum range $p_T^{\text{jet}} > 30$ GeV/c. Next-to-leading order perturbative QCD predictions are in good agreement with the measured cross sections.

1. INTRODUCTION

The study of the production of electroweak bosons in association with jets of hadrons in the final state constitutes a fundamental item in the high-$p_T$ physics program at the Tevatron. These events are main backgrounds to many interesting physics processes like, for example, top production, the search for the SM Higgs, and supersymmetry. The CDF experiment has recently published precise measurements on jets in events with a $Z/\gamma^*$ boson in the final state [1], where inclusive jet cross sections as a function of jet transverse momentum and jet multiplicity are measured and compared to pQCD predictions [2]. At the leading order (LO) in pQCD, $Z/\gamma^*$+jet events are driven by the processes $gq \to Z/\gamma^*+q$ and $q\bar{q} \to Z/\gamma^*+g$, while higher orders contributions, including additional parton radiation, produce multiple jets in the final state. Next-to-leading order (NLO) pQCD predictions for $Z/\gamma^*$+jets production are only available for jet multiplicities $N_{\text{jet}}$ up to $N_{\text{jet}} = 2$. This contribution presents updated results with an increased data sample corresponding to a total integrated luminosity of 2.5 fb$^{-1}$.

2. EVENT SELECTION

The events are required to have two electrons with $E_T^e > 25$ GeV and a reconstructed invariant mass in the range $66 < M_{ee} < 116$ GeV/c$^2$ around the $Z$ boson mass. The electron candidates are reconstructed using criteria described in [3]. In this study, one electron is required to be central ($|\eta| < 1$) and fulfill tight selection cuts, while the second electron is required to pass a looser selection and to be either central or forward with $1.2 < |\eta| < 2.8$. The events are selected to have a reconstructed primary vertex with $z$-position within 60 cm around the nominal interaction point, and at least one jet with transverse momentum $p_T^{\text{jet}} > 30$ GeV/c, rapidity in the range $|y^{\text{jet}}| < 2.1$, and $\Delta R_{e-jet} > 0.7$, where $\Delta R_{e-jet}$ denotes the distance between the jet and each of the two electrons in the final state. The main backgrounds to the $Z/\gamma^* (\to e^+ e^-)$+jets sample arise from inclusive-jets and $W$+jets events, and are estimated from the data. Other background contributions from $t\bar{t}$, $Z/\gamma^* (\to e^+ e^-) + \gamma$, $WW$, $WZ$, $ZZ$, and $Z/\gamma^* (\to \tau^+ \tau^-)$+jets final states are estimated using Monte Carlo samples. The total background in inclusive $Z/\gamma^* (\to e^+ e^-)$+jets production is about 12% for $N_{\text{jet}} \geq 1$, and increases up to about 17% for $N_{\text{jet}} \geq 3$.

3. UNFOLDING PROCEDURE

The measured cross sections are corrected for acceptance and smearing effects back to the hadron level using PYTHIA-TUNED Monte Carlo event samples [4, 5], CTEQ5L [6] parton distribution functions (PDFs) for the proton and antiproton, and a bin-by-bin unfolding procedure that also accounts for the efficiency of the $Z/\gamma^* (\to e^+ e^-)$ selection criteria. The final results refer to hadron level jets with $p_T^{\text{jet}} > 30$ GeV/c and $|y^{\text{jet}}| < 2.1$, in a limited and well-defined kinematic range for the $Z/\gamma^*$ decay products: $E_T^e > 25$ GeV, $|\eta^e| < 1.0$, $|\eta^\tau^1| < 1.0$ or $1.2 < |\eta^\tau^2| < 2.8$.
66 < M_{ee} < 116 GeV/c^2, and \Delta R_{e-jet} > 0.7. In order to avoid any bias on the correction factors due to the particular PDF set used, which translates into slightly different simulated \( p_{T,\text{jet}} \) distributions, the PYTHIA-TUNE A Monte Carlo event sample is re-weighted until it accurately follows the measured \( p_{T,\text{jet}} \) spectra. The unfolding factors \( U(p_{T,\text{cor}}) = \frac{dp_{T,\text{jet}}}{dp_{T,\text{cor}}} \) are computed separately for the different measurements and vary between 2.0 at low \( p_{T,\text{jet}} \) and 2.3 at high \( p_{T,\text{jet}} \).

4. COMPARISON WITH PQCD PREDICTIONS

Figure 1(top) shows the measured inclusive jet differential cross sections as a function of \( p_{T,\text{jet}} \) (black dots) in \( Z/\gamma^* (\rightarrow e^+e^-)+\text{jets} \) with \( N_{\text{jet}} \geq 1, 2 \) compared to NLO pQCD predictions (open circles). For clarity, the measurement for \( N_{\text{jet}} \geq 1 \) is scaled up by \((\times 20)\). The shaded bands show the total systematic uncertainty, except for the 5.8% luminosity uncertainty. (middle and bottom) Data/theory ratio as a function of \( p_{T,\text{jet}} \) for \( N_{\text{jet}} \geq 1, 2 \), respectively. The dashed and dotted lines indicate the PDF uncertainty and the variation with \( \mu \) of the NLO pQCD predictions, respectively.
Good agreement is observed between the measured cross sections and the nominal theoretical predictions.

Finally, Fig. 2 shows the cross sections $\sigma_{N_{\text{jet}}}$ for $Z/\gamma^* \rightarrow e^+ e^-$+jets events up to $N_{\text{jet}} \geq 3$. The data are compared to LO and NLO pQCD predictions. The parton-to-hadron non-perturbative corrections vary between 1.1 and 1.4 as $N_{\text{jet}}$ increases. The LO pQCD predictions underestimate the measured cross sections by a factor about 1.4 approximately independent of $N_{\text{jet}}$. Good agreement is observed between data and NLO pQCD predictions.

The final data sample collected by the CDF experiment in Run II, where more than 6 fb$^{-1}$ are expected, will make possible further detailed studies of the event topologies.

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