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W/Z+JETS AND Z p_T MEASUREMENTS AT TEVATRON

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We present a measurement of W/Z boson + jets production and Z p_T measurement in the $p\bar{p}$ collisions at the Tevatron Collider at $\sqrt{s} = 1.96$ TeV. The CDF II measures W+jets production based on 320 pb^{-1} and the DØ Run II measures Z+jets with 950 pb^{-1} data. The measurement of Z p_T is performed with DØ Run II data corresponding to an integrated luminosity of 960 pb^{-1}. The measurement of W + jets is compared to the Leading Order Alpgen + Pythia prediction and the Z+jets is compared to Sherpa and Pythia Monte Carlo. The Z p_T measurement is also compared to Resbos+Photos predictions.

Keywords: pQCD; boson; jets; Alpgen; Pythia; Sherpa; Resbos.

1. Introduction

The study of jet production containing a W or Z boson is important for understanding perturbative quantum chromodynamics (pQCD). Also the measurement of the W/Z+jets production validates Monte Carlo simulation programs capable of handling particles in the final state at leading order (LO), or in some case, next-to-leading order (NLO) as demanded for physics at the Tevatron and the Large Hadron Collider. The associated vector boson processes are also signatures for the important physics searches, Top, Higgs boson, and SUSY productions. However the W/Z+jets process is a main background for those physics process because of a large production cross section. Therefore the knowing of the cross section and kinematic properties of W/Z+jets production are essential for reliable background estimates.

The weak boson (W and Z) at Tevatron is mainly produced through the quark and anti-quark annihilation and its p_T distribution is a result of the initial state QCD radiations. The differential cross section of the weak boson can not be calculated at a finite order of pQCD at very low transverse momentum, where multiple soft gluon radiation dominates and the calculation diverges. A precision measurement of the weak boson p_T is a test of pQCD at high p_T region and resummation in the low p_T region. The understanding of the boson p_T distribution can reduce the uncertainty in the W mass measurement. It also provides a hint of new physics by looking any deviation at the high p_T region. At Tevatron, we use the clean Z events to measure the boson p_T .

2. W+jets production

The measurement of the W+jet cross section as a function of relevant jet kinematic variables[1] is performed using the Collider Detector at Fermilab (CDF) based on an integrated luminosity of 320 pb^{-1}. Cross sections have been corrected to particle level jets, and are defined within a limited W decay phase space. This closely matches that which is experimentally accessible and minimizes the model dependence that can enter a correction back to the full W cross section. The W events are selected by requiring a good electron of $E_T > 20$ GeV in the central region ($|\eta| < 1.1$) and the missing transverse energy to be greater than 30 GeV. Then the W events are classified according to their jet multiplicity into four n-jet samples. The jet is searched for using an iterative seed-based cone algorithm[2], with a cone radius R=0.4 and is required to have a transverse energy $E_T > 15$ GeV and a pseudorapidity $|\eta| < 2.0$.

Fig. 1 and 2 shows cumulative and differential cross section as a function of the E_T of the first, second, third, and fourth leading jet, respectively. The measurement spans over three orders of magnitude in cross section and close to 200 GeV in jet E_T for the $\geq$1-jet sample. For each jet multiplicity, the jet spectrum is reasonably well described by individually normalized Alpgen[3]+Pythia[4] W+n-parton samples. Also Alpgen+Pythia Monte Carlo has been found to model the shape of the cross section as a function of an invariant mass and angular correlation of two leading jets.

3. Z+jets production

The measurement of the Z+jet cross section as a function of relevant jet kinematic variables[5] are performed using the DØ detector at the Tevatron collider at $\sqrt{s}$=1.96 TeV. The measurement is based on an integrated luminosity of 950 pb^{-1}.

The Z events are selected by requiring two high transverse momentum electrons $p_T > 25$ GeV. At least one of the electrons is required to be reconstructed in the central region $|\eta| < 1.1$ and the other is to be within $|\eta| < 2.5$. The electrons are required to have electromagnetic energy fraction larger than 90% and di-electron invariant mass is to be between 70 GeV and 100 GeV. Jets are reconstructed by using DØ Run II cone algorithm[6] and are required to have $p_T > 15$ GeV. Jets are also required to be separated to the electrons larger than ΔR=0.5.

The observed jet multiplicity distribution is compared to the Pythia[7] in Fig. 3 and Sherpa[8] in Fig. 4. Both Monte Carlo predictions are normalized to the total number of Z/γ^* events found in the data sample, however, no separate normalization is performed for the various Z+jet classes. The central values of the Sherpa predictions are somewhat higher than in data, where Pythia tends to produce too few multi-jet events. However, the both predictions are in agreement with data within errors.

The p_T distribution of di-electron system and the differential cross section for the leading, second and third jets are also com-

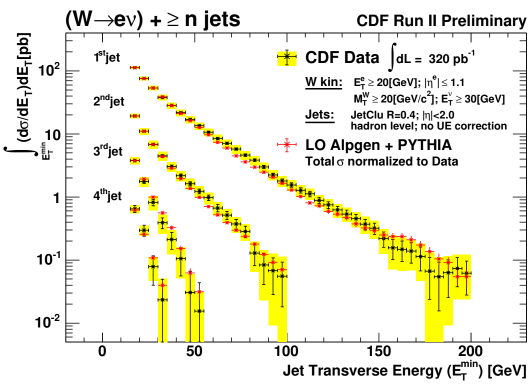

Fig. 1. Cumulative cross section of W+n jets as a function of the minimum E_T for the first, second, third, and fourth inclusive jet sample. Data are compared to Alpgen+Pythia predictions normalized to the measured inclusive cross section in each jet multiplicity.

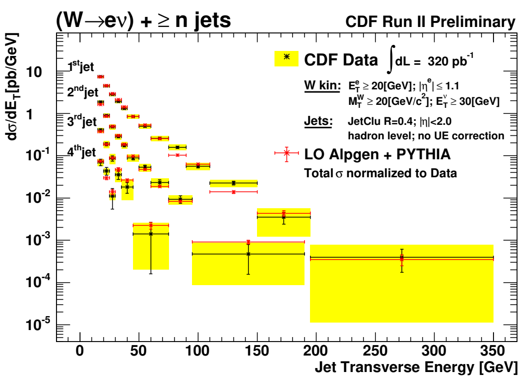

Fig. 2. Differential cross section of W+n jets as a function of the minimum E_T for the first, second, third, and fourth inclusive jet sample. Data are compared to Alpgen+Pythia predictions normalized to the measured inclusive cross section in each jet multiplicity.

pared to the both prediction. Measurements show that the Pythia predicts too few hard jets and Sherpa prediction is mostly consistent with data within errors. Angular correlations between two hardest jets are interesting to study because a large opening angle is expected to receive large interference contributions included in a matrix element description, but partially modeled in parton shower approaches. Overall agreement for angular correlations between two hardest jets between data and both predictions are good except at $\Delta\phi = \pi$ where a significant peak in the Pythia prediction. In conclusion, the Sherpa Monte Carlo, combining parton shower and matrix element description of jets using the CKKW algorithm[9,10], has been found to describe the jet properties better.

4. Z p_T distribution

The differential cross section of Z/γ^* decays to e^+e^- as a function of boson transverse momentum[11] is performed using the DØ detector at Fermilab. The data sample used for this measurement corresponds to an integrated luminosity of 960 pb^{-1}. The event selection for Z/γ^* candidates requires two isolated energy clusters in the electromagnetic calorimeters. Two high p_T isolated electrons for central ($|\eta| < 1.1$)-central, central-endcap ($1.5 < |\eta| < 3.2$), endcap-endcap regions are selected and its di-electron invariant mass is required to be between 70 and 110 GeV/c^2.

The measured p_T distribution is smeared due to detector resolution effects therefore the measured Z boson p_T spectrum is unfolded to compare with theory directly. The observed Z boson p_T distribution is shown in Fig. 5 and is compared to the predictions based on Resbos[12]+Photos[13] Monte Carlo, with CTEQ6.1m parton distribution function. Also it is compared to the same prediction with small x-correction based on an updated resummation technique developed to understand the p_T distribution in semi-inclusive deep inelastic scattering data. As seen in Fig. 5, both predictions describe the data well.

The Z boson p_T distribution for Z rapidity of >2 is expected to be available soon, which will test for an updated resummation

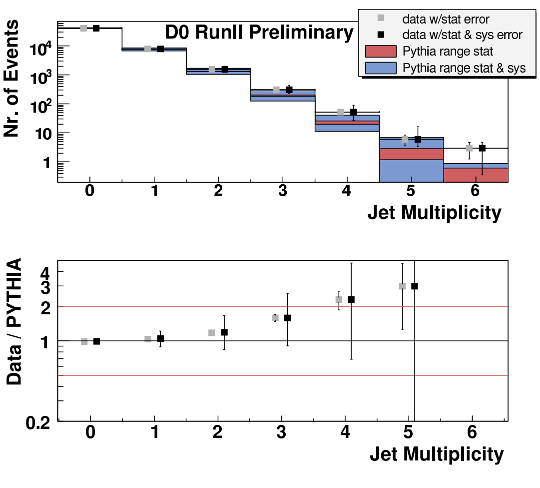

Fig. 3. Jet multiplicity distribution in the Z+jets sample. Data are compared to the Pythia prediction. The lower plot shows the ratio, data/MC. The red line indicate a factor 2 up and down.

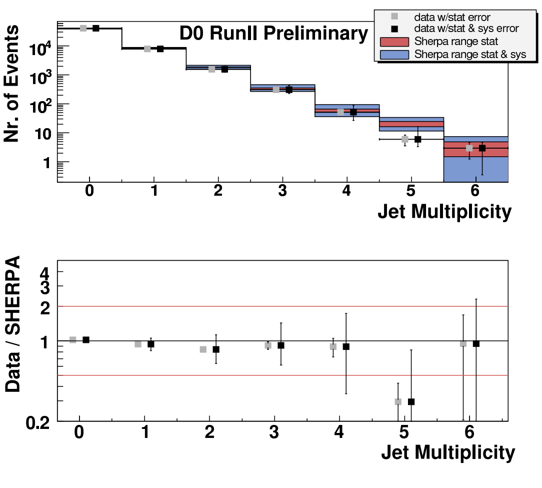

Fig. 4. Jet multiplicity distribution in the Z+jets sample. Data are compared to the Sherpa prediction. The lower plot shows the ratio, data/MC. The red line indicate a factor 2 up and down.

technique that predicts a small-x broadening [14].

5. Conclusions

The CDF has a measurement of W+jets production based on 320 pb^{-1} and the measurement is compared to the normalized Alpgen+Pythia prediction. Comparisons show reasonable agreement between the measured cross section and the predictions. The DØ has measured Z+jets production with 950 pb^{-1} and compared to the Pythia and Sherpa predictions. The measurement is consistent with the Sherpa prediction within errors. Also the DØ has a new measurement of Z p_T distribution based on 960 pb^{-1} and has compared to the Resbos+Photos Monte Carlo. It shows that the Monte Carlo describes the measurement well.

We expect that Tevatron continues to provide improved results on vector boson (W/Z)+jets production and boson p_T distribution.

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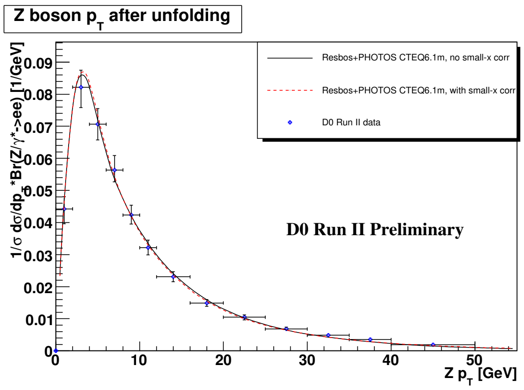

Fig. 5. Z boson p_T distribution. Data are compared to the Resbos+Photos prediction. Dotted line is the Resbos+Photos prediction with small x-correction based on an updated resummation technique. The error contains both statistical and systematic uncertainties.

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