W + JET PRODUCTION AT CDF

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A measurement of $W \to e\nu + n-$jet cross sections in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV using the Collider Detector at Fermilab in Run II (CDF II) is presented. The measurement is based on an integrated luminosity of 320 pb^{-1}, and includes events with up to 4 or more jets. In each jet multiplicity sample the differential and cumulative cross sections with respect to the transverse energy of the i^{th} jet are measured. For $W+ \geq 2$ jets the differential cross section with respect to the 2-leading jets invariant mass $m_{j_1 j_2}$ and angural separation $\Delta R_{j_1 j_2}$ is also reported. The data are compared to predictions from Monte Carlo simulations.

The study of jets produced in events containing a W bosons provides a useful test of Quantum Chromo-Dynamics (QCD) at high momentum transfers. Recently a lot of work has been channeled to develop sophisticated Monte Carlo programs capable of handling more particle in the final state at the leading order (LO), or in some cases, next-to-leading order (NLO) [1]. Measurements of W + jet cross sections are an important test of QCD and may be used to validate these new approaches. A good understanding of W + jet production is vital to reduce the uncertainty on the background to top pair production and to increase the sensitivity to higgs and new physics searches at the Tevatron and the LHC.

This contribution describes a new measurement of the W + jet cross section as a function of relevant jet kinematic variables. Cross sections have been corrected to particle level jets, and are defined within a limited W decay phase space, closely matching that which is experimentally accessible. This definition, easily reproduced theoretically, minimizes the model dependence that can enter a correction back to the full W cross-section. This analysis is based on 320 ± 18 pb^{-1} of data collected by the CDF II detector at Tevatron collider.

The CDF II detector [2] is an azimuthally and forward-backward symmetric apparatus situated around the $p\bar{p}$ interaction region, consisting of a magnetic spectrometer surrounded by calorimeters and muon chambers. $W \rightarrow e\nu$ candidate events are selected from a high E_T electron trigger ($E_T^e \geq 18$ GeV, $|\eta^e| < 1.1$) by requiring one good quality electron candidate ($E_T^e \geq 20$ GeV) and the missing transverse energy ($\not\!\!E_T$) to be greater than 30 GeV. The $W \rightarrow e\nu$ candidate events are then classified according to their jet multiplicity into four n−jet samples ($n \geq 1,\ 4$). Jet are searched for using an iterative seed-based cone algorithm [3], with a cone radius $R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.4$. Jets are requested to have a corrected transverse energy $E_T^{jet} > 15$GeV and a pseudorapidity $|\eta| < 2.0$. E_T^{jet} is corrected on average for the calorimeter response and the average contribution to the jet energy from additional $p\bar{p}$ interaction in the same bunch crossing [4].

Backgrounds can be classified in two categories: QCD and W-like events. The latter is represented by events which manifest themselves as real electrons and/or $\not\!\!E_T$ in the final state, namely: $W \rightarrow \tau\nu$, $Z \rightarrow e^+e^-$, WW, top pair production. The former is mainly coming from jets production. While the W-like backgrounds are modeled with Monte Carlo simulations, the QCD background is described with a data-driven technique. To extract the background fraction in each $W+ \geq n-$jet sample the $\not\!\!E_T$ distribution of candidates is fitted to background and signal templates. `Alpgen` [5] interfaced to `HERWIG` [6] has been used to generate the $W \rightarrow \tau\nu$, $Z \rightarrow e^+e^-$ backgrounds and the W signal, `PYTHIA` [7] have been used for top and WW backgrounds. The sensitivity of these template on the particular set of parton level cuts and Monte Carlo parameters has been studied. It is always below a 5% level and this effect has been included in the systematic on the background estimate. The template for the QCD background is extracted from the data selecting a background enriched sample using candidate electron satisfying all standard quality requirements but at least failing two of them. Cross-checks of this method have been performed by looking to other W kinematic distributions as the transverse mass of the W m_T^W and the electron E_T^e. In all these variables a very good agreement between data and background models has been found. The total background fraction ranges from 1% at low jet multiplicity and low E_T^{jet} to 80% at high E_T^{jet} and is largely dominated by the contribution of QCD. At high jet multiplicity and high E_T^{jet}, the contribution to the background from top production is sizeable ($\geq 50\%$). In this region the uncertainty on the top pair production cross section dominates the background systematic. Elsewhere the main contribution to the uncertainty on the background fraction comes from the limited statistic of the QCD background sample.

A full detector simulation has been used to take into account selection efficiencies, coming from geometric acceptance, electron identification and $\not\!\!E_T$ and E_T^e resolution effects. The full CDF II detector simulation accurately reproduces electron acceptance and identification inefficiencies: no evidence of a difference between data and simulation have been found in the $Z \rightarrow e^+e^-$ sample. To minimize the theoretical uncertainty in the extrapolation of the measurement, the cross section has been defined for the W phase space accessible by the CDF II detector: $E_T^e > 20\text{GeV}$, $|\eta^e| < 1.1$, $\not\!\!E_T > 30\text{GeV}$ and $m_T^W > 20\text{GeV/c}^2$. This eliminates the dependence on Monte Carlo models to extrapolate the visible cross section to the full W phase space. Nevertheless Monte Carlo events have been used to correct for inefficiency and boundary effects on the kinematic selection that defines the cross section. Different Monte Carlo prescriptions have been checked and the critical parameters have been largely scanned. These effects turned out to be at the 5% level at low E_T^{jet}. They have been included into the systematic uncertainty on the efficiency which is $(60 \pm 3)\%$, largely independent of the jet kitematic.

The candidate event yields, background fractions and efficiency factors are combined to form the raw W + jet cross sections. The raw cross sections are then corrected back to the hadron level jet cross sections using Monte Carlo event samples. `Alpgen` interfaced with `PYTHIA-TUNE A` [8] provides a reasonable description of the jet and underlying event properties, and is used to determine the correction factors, defined as the ratio of the hadron level cross section to the raw reconstructed cross section.

The measured cross section are shown in fig. 1. Results are presented as both cumulative $\sigma(W \rightarrow e\nu+ \geq n - \text{jets}; E_T^{jet}(n) > E_T^{jet}(min))$ and differential $d\sigma(W \rightarrow e\nu+ \geq n - \text{jets})/dE_T^{jet}$ distribution where E_T^{jet} is that of the i^{th}−jet (Top plots fig. 1). 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`+`PYTHIA` $W + n -$ parton samples. The shape of the dijet invariant mass and angular correlation (Bottom plots fig. 1) are also well modeled by the same theory prediction. The systematic error is dominated by the uncertainty on the jet energy scale ($\sim 3\%$) at low E_T^{jet}, while at high energy the dominant contribution comes from the uncertainty on the background fraction, in particular from the limited statistic of the QCD background sample. We expect to reduce drastically this effect by increasing the statistic of the data sample. We are currently working on similar measurements in the $Z+ \geq n-$jets events.

This event sample, thanks to the low background contamination and to the closed kinematic, is also particularly suitable to study the underlying event and the jet shape.

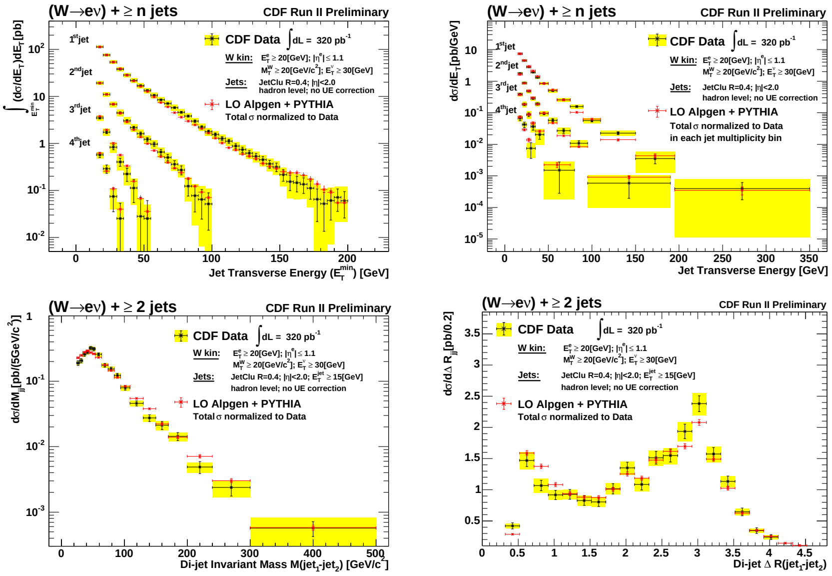

Figure 1. Top: Cumulative cross section $\sigma(W \rightarrow e\nu + \geq n - \text{jets}; E_T^{jet}(n) > E_T^{jet}(min))$ as a function of the minimum $E_T^{jet}(min)$ (Left) and differential cross section $d\sigma(W \rightarrow e\nu + \geq n - \text{jets})/dE_T^{jet}$ (Right) for the first, second, third and fourth inclusive jet sample. Bottom: Differential cross section $d\sigma(W \rightarrow e\nu + \geq 2 - \text{jets})/dM_{j1j2}$ (Left) and $d\sigma(W \rightarrow e\nu + \geq 2 - \text{jets})/dR_{j1j2}$ (Right) respectively as a function of the invariant mass and angular separation of the leading 2 jets. Data are compared to `Alpgen`+`PYTHIA` predictions normalized to the measured cross section in each jet multiplicity sample.

References

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