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Production of Jets in Association with W Vector Bosons in the DØ Detector

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ABSTRACT

The DØ detector has been accumulating data at the Fermilab Tevatron at $\sqrt{s}=1.8$ TeV for several months. In this paper we present the results of an analysis based on $1.1pb^{-1}$ of data. We compare the observed W transverse momentum distributions of W+0jet and W+1jet events with a full DØ detector simulated leading order Monte Carlo. The jet multiplicity distributions associated with the W are presented as well as a new method of testing NLO QCD predictions and measuring the strong coupling constant α_s.

1. Introduction

Jet production in association with W provides a good tool for testing QCD predictions. Now that the next to leading order (NLO)[2,3] calculations for W+0jet and W+1jet cross sections are available, we can check the accuracy of NLO calculation and estimate corrections from higher order contributions. The W+jets process was used by the UA1 and UA2 experiments to measure the strong coupling constant α_s. This was done by taking the ratio of the cross-sections of W+1jet to W+0jet processes using a single fixed jet algorithm. In addition to the above two physics objectives, multi jet production in assosiciation with W's is one of the major background sources for the top search. For instance, W+$n$jet where $n>2$ with a leptonic decay of the W is the major background to the top decay channel of lepton + 4jets.

2. Event Selection Criteria

The integrated luminosity for this analysis is $1.1pb^{-1}$. Among the several triggers in DØ for W candidates with the final state of $e+\nu_e$, this analysis concentrates on one particular set of triggers. A hardware trigger (level 1) requires at least one electromagnetic (EM) trigger tower (0.2x0.2 in $\eta-\phi$ space) with $E_T>14$ GeV. The subsequent level 2 trigger requires at least one EM cluster with $E_T>20$ GeV with cluster shape cuts and missing $E_T>20$ GeV. There is no particular requirement for jets at the trigger level. The efficiency of this particular set of triggers for W's including geometric acceptance is estimated to be 56%. We have also studied the trigger efficiency for W+multi jet events and the efficiency is the same up to W+4jet events within our error. We impose offline cuts on reconstructed events with the following criteria: First, an event must have at least one electron with $E_T > 20$GeV and missing $E_T > 20$ GeV. Second, we impose a set of electron quality cuts. These quality cuts are: 1) $\chi^2 < 200$ which reflects how well the transverse and longitudinal shower profile agrees with a standard DØ test beam electron profile; 2) The ratio of the difference between the total energy in a cone of size 0.4 around a cluster core and the EM energy in a core cone of size 0.2 divided by the EM energy in the 0.2 cone must be less than 0.1 to ensure an electron is isolated from other objects; 3) We also imposed matching between the calorimeter cluster and a charged track by requiring $|\Delta\phi| < 0.05$ and $|\Delta\theta| < 0.07$. With the above offline criteria, tracking efficiency, and trigger efficiency taken into account, the final efficiency for W events is 31%±5% and remains the same up to W+4jet events within our error.

3. The final event sample and backgrounds

With the event selection criteria described in the previous section, we have found 882 W ($\rightarrow e + \nu_e$) candidates before background subtraction. The transverse mass of the W candidates has a Jacobian peak as expected with a sharply falling edge at the W mass with a shoulder in the lower mass region[5].

We have identified three probable sources of background. 1) Backgrounds from $W \rightarrow \tau + \nu_\tau$, where τ subsequently decays into $e+\nu_e+\nu_\tau$ are estimated to be about 5% which corresponds to 44 events. However, for this particular analysis this process does not play a role because as far as associated jet production is concerned, we assume both decay modes have the same characteristics. 2) The background contamination from QCD events is estimated to be much less than 1% mostly due to the large missing E_T and isolation requirements. 3) Z_0's can contribute as background in the case where we misidentify one of the two electrons. The contribution from this process is estimated to be much less than 1%.

4. Results

We have generated Monte Carlo events based on leading order predictions (VECBOS)[1] and put them through the full DØ detector simulation. The transverse momentum of the W (P_T^W) candidates for W+0jet and W+1jet events were compared with data normalizing the number of events in the Monte Carlo to the number of events in the data. The shapes of the distributions agree well. The P_T^W distributions can also be used to check QCD predictions. However, there is a theoretical uncertainty because in the lower P_T^W region perturbative QCD is no longer applicable due to the lack of asymptotic freedom in the low momentum transfer. Experimentally, a good knowledge of the energy scale for jets and missing E_T is very important because P_T^W calculations are based on these measured quantities.

The NLO theoretical predictions give us a better way of testing QCD predictions. The logarithm of the ratio of cross sections for W+0jet and W+1jet events (R(1J/0J)) can be used. This quantity is insensitive to the parton distributions chosen and to the cone size of jet algorithm used. When we plot this quantity as a function of the jet minimum E_T cutoff (E_T^{min}), we find an unexpected characteristic. This quantity is a linear function of E_T^{min}. We have observed the same behavior in the data. To compare the data with theoretical prediction and to minimize the fluctuations in the data in jet multiplicity distributions, we have fit the jet multiplicity distributions with 4 different E_T^{min} values (12GeV, 15GeV, 20GeV, and 25GeV) for a cone size of 0.7 to exponential functions. We use this parameterization to calculate the ratio above. Fig. 1 is the jet multiplicity distributions with four different E_T^{min}. The straight lines are fits to the data.

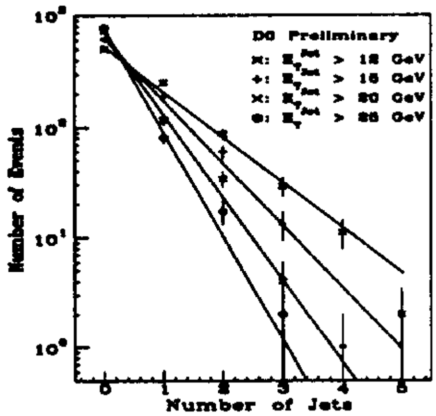

Fig. 1. Jet Multiplicity distributions

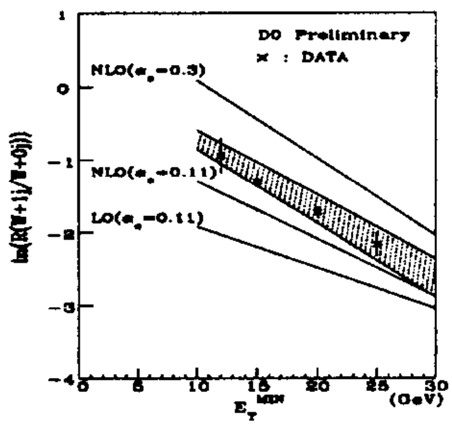

Fig. 2. ln(R(W+1j/W+0j)) vs E_T^{min}

We have also found that this quantity behaves differently depending on the order of the theoretical predictions used. In leading order this quantity is linear in E_T^{min} and as we vary α_s, only the absolute normalization changes. In NLO predictions this quantity changes not only the absolute normalization but also the slope. As is illustrated in Fig. 2, data seem agree with NLO. And by measuring ln(R(1J/0J)) with reasonable accuracy one can also estimate the higher order corrections to the NLO predictions and most importantly measure the strong coupling constant α_s. The shaded area shown in Fig. 2 is the current error due to the uncertainty in jet energy scale.

5. References

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