PDF constraints from CDF

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Recent results from CDF that provide constraints on PDFs are presented. The results are divided into two groups, electroweak measurements which include W charge asymmetry, Z cross-section and Forward Ws and QCD measurements which include the inclusive jet cross-section, Z+b-jet and W+charm analyses. Most of the measurements presented used over 1 fb^{-1} of CDF Run II data.

1 Introduction

The Tevatron lies at a Q^2 in between that of HERA and the LHC and can thus provide information on PDFs that is inaccessible to both. The Tevatron has now collected over 3 fb^{-1} of data on tape and with increased statistics it is able to make significant contributions to global PDF fits. Numerous measurements are underway at CDF that can provide constraints on PDFs, including measurements with W and Z bosons decaying to high p_T leptons and those with jets in the final state.

2 Electroweak Measurements

2.1 $d\sigma/dy(Z/\gamma^* \rightarrow e^+e^-)$

For the Drell Yan process at leading order(LO), the momentum fractions of the interacting partons are directly related to the rapidity of the Z boson in the following way, $x_{1,2} = \frac{M_W}{\sqrt{s}} e^{\pm y_Z}$. The high rapidity region therefore allows us to probe one high-x parton and one low-x parton.

The measurement was carried out in the electron decay channel using 2.1 fb^{-1} of data. The rapidity of the Z boson is well reconstructed from the two leptons in the decay and the analysis includes events where both electrons are in the forward regions of the detector to cover as large a rapidity region as possible. The differential cross-section is measured and shown as a function of the boson rapidity in Figure 1 compared to theoretical prediction from next to leading order(NLO) CTEQ6.1M PDF, where the theory has been normalised to the measured cross-section. The comparison between data and NLO CTEQ6.1M PDF gives $\chi^2/\text{ndf} = 39/30$. Similar comparisons to theoretical predictions from NLO and next to next to leading order(NNLO) MRST PDFs are shown in Figure 2. The results show

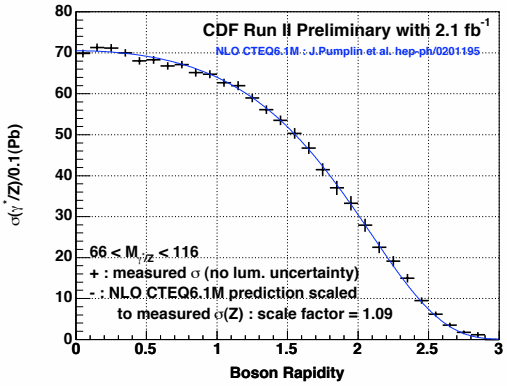

Figure 1: $d\sigma/dy$ for $Z/\gamma* \rightarrow e^+e^-$

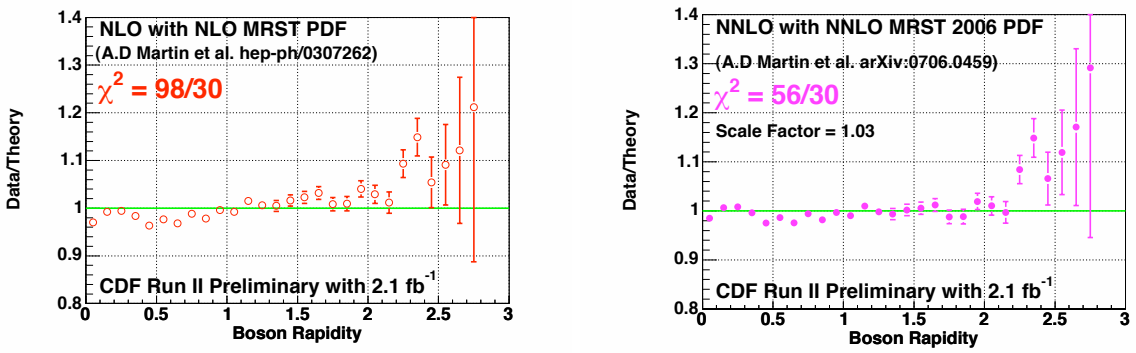

Figure 2: The ratio of data to theory prediction for $d\sigma/dy$.

that in general the data is in good agreement with theoretical predictions but it is most consistent with NLO CTEQ6.1M PDF [1] and between the two MRST comparisons, it is in better agreement with the NNLO MRST prediction.

2.2 W Charge Asymmetry

The W boson at the Tevatron is produced predominantly from a quark in the proton and an anti-quark in the antiproton. The W charge asymmetry arises because the u quark carries a larger fraction of the proton or antiproton's momentum than the d quark. This asymmetry in the momenta of the interacting quarks results in the W^+ begin boosted preferentially in the proton direction and the W^- being boosted in the antiproton direction. The W charge asymmetry is sensitive to the ratio of the d and u momentum distributions and this measurement can therefore provide a valuable constraint on this ratio. The measurement was made using 1 fb^{-1} of data and Figure 3 shows the absolute asymmetry versus the rapidity for data, the NNLO theoretical prediction and also the CTEQ6M PDF uncertainty band. It shows that there is good agreement with the NNLO prediction using MRST2002 PDFs. Also, the experimental uncertainty is comparable to the PDF uncertainty and at high rapidities in particular, the uncertainty on the data is smaller than that on PDFs. This measurement should therefore be a useful input in future PDF fits.

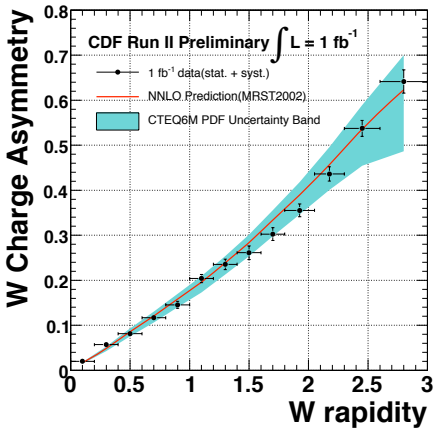

Figure 3: W Charge Asymmetry

2.3 Forward Ws

The Forward W analysis attempts to constrain PDFs by probing different regions of the W rapidity. This is done by independently measuring the W cross-section where the decay lepton is in the forward region of the detector. The analysis was carried out in the electron decay channel using 223 pb^{-1} of data [2]. The total inclusive cross-section for forward electrons is compared to the total cross-section previously measured for central electrons and the two measurements are found to be consistent. A visible cross-section is defined, $\sigma_{vis} = \sigma_{tot} \times A$, where A is the detector acceptance. The ratio of the visible cross-sections in the central and forward regions is taken from the data and compared with the theoretical ratio of acceptances for the central and forward regions. The results are as follows:

$$\begin{aligned} R_{exp} &= \frac{\sigma_{vis}^{cen}}{\sigma_{vis}^{forw}} = 0.925 \pm 0.033 \\ R_{CTEQ6.1} &= \frac{A_{vis}^{cen}}{A_{vis}^{forw}} = 0.924 \pm 0.037 \\ R_{MRST01E} &= \frac{A_{vis}^{cen}}{A_{vis}^{forw}} = 0.941 \pm 0.012 \end{aligned}$$

In general, both CTEQ and MRST agree with data within uncertainties although the central values for CTEQ and MRST are shifted with respect to each other. The results show that CTEQ gives better agreement with data than MRST01. The uncertainties in the experimental ratio are expected to decrease with statistics and the measurement has the potential to provide constraints on PDFs in the future.

3 QCD Measurements

The inclusive jet cross-section measurement provides a powerful constraint on the most uncertain PDF at high x, the gluon PDF. The inclusive jet measurement is made in 5 bins of rapidity. Since no new physics is expected in the high rapidity bins these can be used to constrain PDFs whilst retaining sensitivity to new physics in the lower rapidity bins. Two jet reconstruction algorithms were used for this measurement at CDF, the MidPoint algorithm using 1.13 fb^{-1} of data [3] and the k$_T$ algorithm using 1 fb^{-1} of data [4]. Figure 4 shows the data to theory ratio versus the jet p$_T$ for the 5 rapidity regions using the MidPoint algorithm(left) and the k$_T$ algorithm(right). The results show that the data is consistent with NLO pQCD predictions in all rapidity regions. The experimental uncertainty, in particular in the forward region is smaller than the PDF uncertainty and these measurements therefore look promising for use in future PDF fits.
Other analyses at CDF probe a particular quark density and include the W+charm analysis and the Z+b-jet analysis.

At LO in ppbar collisions, W bosons with a single charm quark can be produced by the scattering of a gluon with a d, s or b quark. The d and b quark are heavily suppressed because of the CKM matrix elements and therefore 90% of the W+charm signal is produced by a strange quark and gluon in the initial state and the production cross-section is therefore directly sensitive to the gluon and s-quark PDFs. The cross-section was measured at CDF using 1.8 fb^{-1} of data and it was found to be: $\sigma_{Wc} \times BR(W \rightarrow l\nu) = 9.8 \pm 2.8(\text{stat.})^{+1.4}_{-1.6}(\text{sys.}) \pm 0.6(\text{lum})\text{pb}$ [5]. The measurement agrees with NLO calculation.

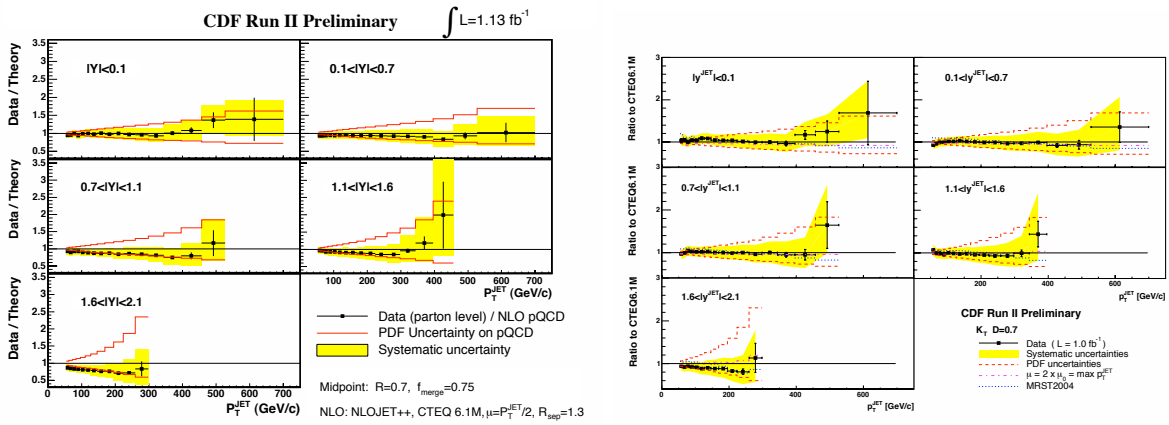

Figure 4: Inclusive jet cross-section measurements using the MidPoint algorithm(left) and the k_T algorithm(right).

However, the uncertainty on the measurement is dominated by statistics and with a better precision expected by the end of Run II this measurement may look more promising in the future for PDF fits.

The Z+b-jet cross-section is sensitive to the b-quark density in the proton which is an important quantity needed to accurately predict the production of particles that couple strongly to b-quarks including the Higgs boson within SUSY models and single top production in the standard model. This cross-section has been measured at CDF with 2 fb^{-1} of data for the electron and muon channels of the Z decay. The cross-section is extracted from the ratio of the Z+b-jet cross-section to the inclusive Z cross-section. The cross section and the ratio were also measured differentially as a function of several variables, including jet E_T. Comparisons of the ratio with Pythia, ALPGEN and MCFM showed that the ratio is in good agreement with Pythia at low jet E_T but ALPGEN and MCFM undershoot the data.

4 Conclusions

A number of analyses at CDF have the ability to place constraints on PDFs. Some of these, notably the W charge asymmetry and inclusive jet cross-section will make a significant contribution to PDF fits. Other analyses look promising and with higher statistics may also provide useful information on PDFs.

References

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[4] A.Abulencia *et al*, Phys. Rev. **D 75**, 092006 (2007)

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