PDF Constraints From Tevatron Data

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Abstract
Recent measurements from the CDF and DØ experiments at the Fermilab Tevatron collider that constrain parton distribution functions are presented. These include inclusive jet cross section data and measurements of rapidity distributions in W and Z events.

1 Introduction

The Tevatron p$\overline{\text{p}}$ collider presently provides the world's highest energy collisions at a centre of mass energy of 1.96 TeV. Analyses constraining Parton Distribution Functions (PDFs) based on 4 fb^{-1} of integrated luminosity are presently being undertaken and the ultimate constraints are expected to come from datasets of approximately 8 fb^{-1}. The results presented in these proceedings are from $0.2 - 2.0$ fb^{-1} of data taken in 2003-2006. At present PDF constraints are derived from cross section measurements of inclusive jets and the rapidity distributions of W and Z bosons. Ultimately it may be possible to derive PDF constraints from W/Z,γ + jet/heavy-flavour data but to date uncertainties in the underlying QCD calculation have precluded meaningful PDF constraints. In terms of the global PDF fits, the Tevatron provides approximately 10% of the data-points. The data complement that of the HERA and fixed target experiments and provide constraints in the high-Q^2 region which has some overlap with the highest Q^2 HERA data at high x and crucially with the LHC at the Q^2 scale of electroweak symmetry breaking.

2 Inclusive Jet Data

Two Tevatron inclusive jet cross section data are presently included in the PDF global fits : DØ data [1] based on 0.7 fb^{-1} of integrated luminosity with jets reconstructed using the cone algorithm in the kinematic region $50 < E_T < 600$ GeV, $|y| < 2.4$ and CDF data [2] based on 1.0 fb^{-1} of integrated luminosity with jets reconstructed using the k_T algorithm in the kinematic region $54 < E_T < 700$ GeV, $|y| < 2.1$. CDF data [3] with jets reconstructed using the mid-point algorithm are used as a systematic cross-check. In the global PDF fits the jet data have their largest impact in constraining the gluon distribution at high-x ($0.01 < x < 0.5$) which is particularly important for reliably determining the Standard Model background to new physics searches at the LHC. The Tevatron inclusive jet data now have far greater statistical precision than the data used in previous fits from Run-1. The systematics of the procedure used to correct the data back to the parton level is also far better controlled than was the case in Run-1. The CDF data are shown in figure 1 and the DØ data in figure 2.

The systematic uncertainties in these measurements are largest at high E_T with the determination of the jet energy scale providing the largest contribution to the systematic uncertainty. The latest PDF fits provide an excellent fit to the jet data and are found to be most stable when a

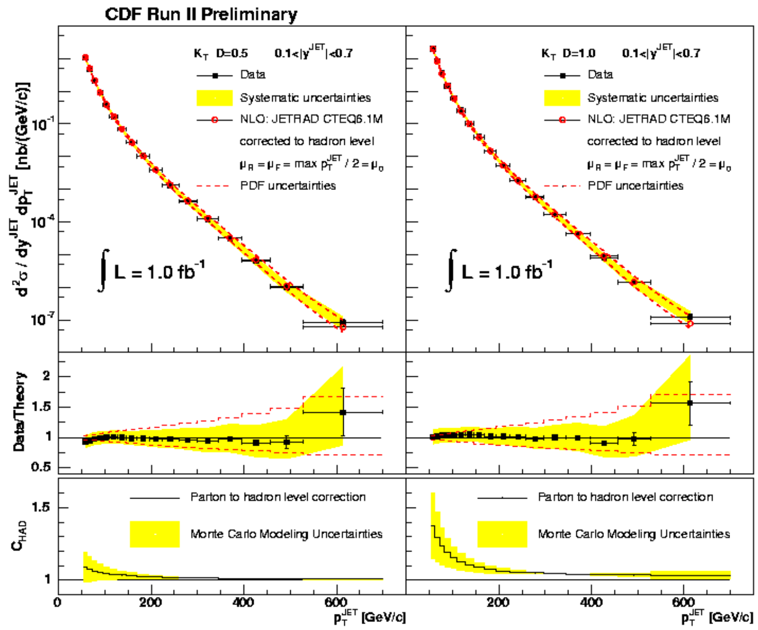

Fig. 1: CDF inclusive jet cross sections compared to NLO predictions.

scale of jet E_T not $E_T/2$ is used. The gluon distribution at high x from the preliminary MSTW analysis [4] is shown in figure 3.

The latest fit is softer at high x compared to previous fits based on the Tevatron Run-1 jet data and the fit is consistent to a fit not including any Tevatron jet data. The fit is also in agreement with the latest CTEQ 6.6 fit [5] and the MSRT 2004 [6] fit. The variance in the gluon distribution is somewhat reduced but more data at high x will be required to reduce the variance below 50% at the highest x values. Further improvements in understanding the jet energy scale from higher statistics control samples will also help reduce the systematic uncertainties in the data.

3 W and Z Rapidity Constraints

The rapidity distributions of W and Z bosons can be measured rather precisely at the Tevatron and to date four measurements have been used to constrain PDFs. They are the DØ measurement [7] of the Z rapidity based on 0.4 fb^{-1} of $Z \rightarrow e^+e^-$ data, a preliminary CDF measurement [8] from 2.0 fb^{-1} of $Z \rightarrow e^+e^-$ data, a DØ measurement [9] of the W charge asymmetry using $W \rightarrow \mu\nu$ events from 0.3 fb^{-1} of data and the CDF measurement [10] of the same quantity using 0.2 fb^{-1} of $W \rightarrow e\nu$ data. The latest CDF and DØ data on the W charge asymmetry is not yet included in the global PDF fits since a consistent fit to the the two datasets has not been yet been possible and is under investigation by the collaborations. The Tevatron W and Z data are in principle sensitive to the up and down quark PDFs. However owing to the e_Q^2 weighting

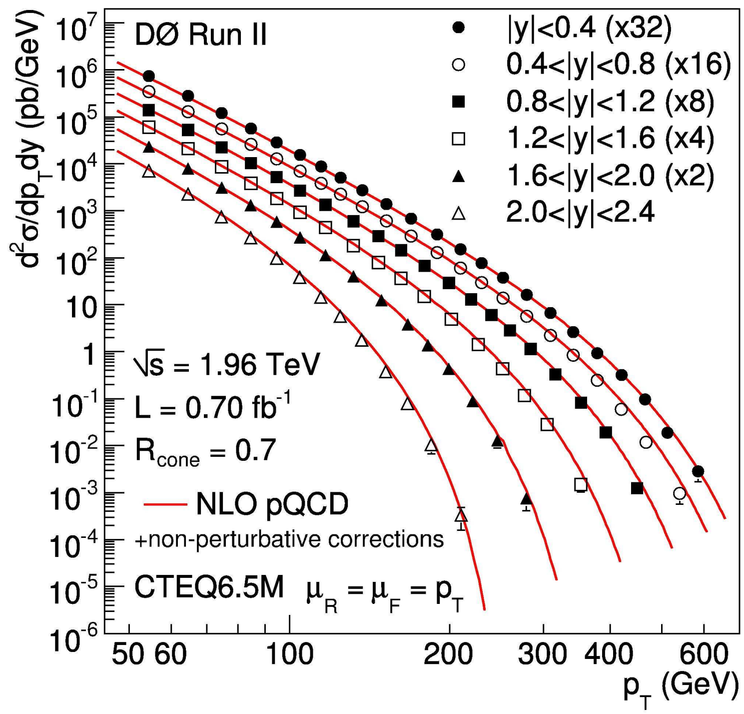

Fig. 2: DØ inclusive jet cross sections compared to NLO predictions.

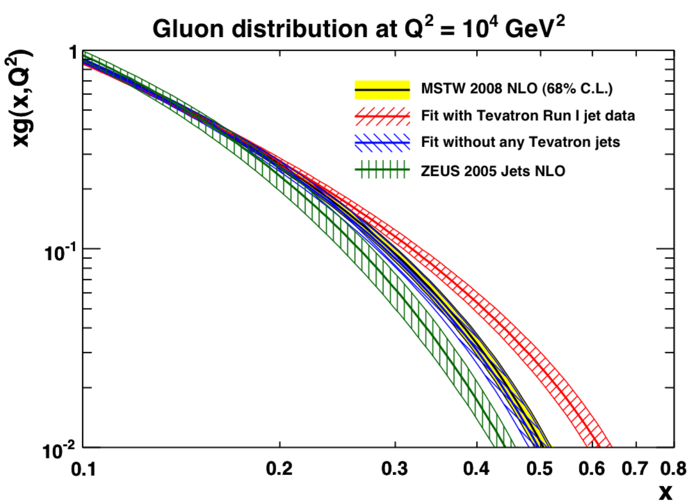

Fig. 3: The gluon distribution at high x from the preliminary MSTW analysis compared to gluon distributions including (or not) the Run-1 Tevatron jet data.

in F_2, the up quark distribution is rather well constrained by the HERA F_2 data and so the Tevatron data mostly provide a constraint on the down valence quark distribution. Z events at high rapidity probe one high x and one low x parton. Both the CDF and DØ data are well described by the latest and previous global PDF fits, with the best description presently provided by the CTEQ6.1 [11] PDFs. The down valence distribution from the preliminary MSTW analysis is shown in figure 4. Previous down valence distributions were rather unstable in the high x region. The new data has allowed the number of constraining parameters to be increased and a more robust distribution to be obtained. The variance on the distribution is now larger but believed to be a more reliable estimate of the uncertainty compared to previous fits. The uncertainty in the high x region, like the gluon, is again significant.

W^+ bosons at the Tevatron are preferentially boosted along the incoming proton direction since the up valence quark carries on average more momentum than the down valence quark. A measurement of the W charge asymmetry as a function of rapidity therefore provides constraints on d/u. Some discrimination between valence and sea quark contributions can be obtained by measuring the charge asymmetry as a function of the lepton E_T since the sea quark contribution is enhanced at low E_T. Published measurements [9, 10, 12] have used the lepton charge asymmetry but recently CDF [13] has unfolded the measurements back to the W rapidity which in principle provides more information since the PDF information is not convoluted with the $V - A$ decay structure. The data is weighted by the two solutions of Y_W based on kinematic constraints informed by the MC. The unfolding is an iterative one to remove the dependence on the MC input parameters, particularly the PDFs.

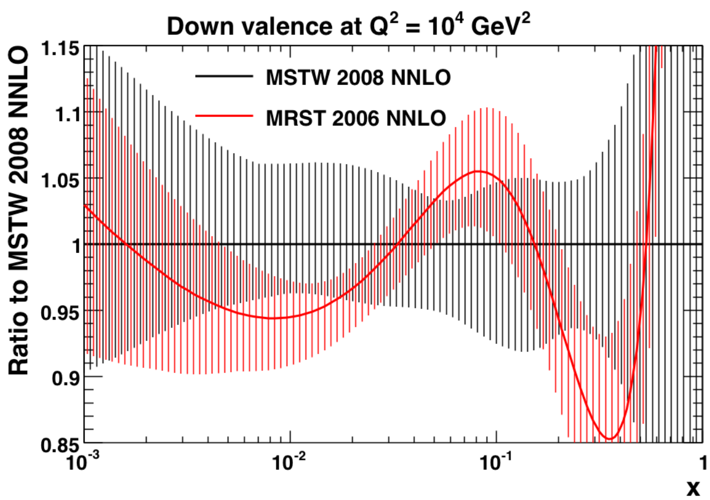

Fig. 4: The down valence quark distribution from the preliminary 2008 MSTW analysis which includes the latest Tevatron Z rapidity data to an older fit without the data.

4 Other Potential Measurements to Constrain PDFs

The measurements presented above are the only Tevatron measurements presently included in global PDF fits. There are a number of other measurements which with greater statistics and improved modeling of the underlying QCD could in principle provide valuable PDF information. These include a measurement of the W cross section ratio at high and low rapidity and measurements of jet + vector boson (W,Z,γ) cross sections where additional flavour information can also be established by tagging bottom and charm jets.

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References

[1] DØ Collaboration, V. Abazov *et al.*, Phys. Rev. Lett. **101**, 062001 (2008).

[2] CDF Collaboration, A. Abulencia *et al.*, Phys. Rev. **D75**, 092006 (2007).

[3] CDF Collaboration, A. Abulencia *et al.*, hep-ex/0807.2204 (2008) .

[4] G. Watt, A. D. Martin, W. J. Stirling and R. S. Thorne, hep-ph/0806.4890 (2008); and W. J. Stirling in these proceedings .

[5] P. Nadolsky *et al.*, Phys. Rev. **D78** 013004 (2008) .

[6] A.D. Martin, R.G. Roberts, W.J. Stirling and R.S Thorne, Phys. Lett. **B604** 61 (2004).

[7] DØ Collaboration, V. Abazov *et al.*, Phys. Rev. **D76**, 012003 (2007).

[8] CDF Collaboration, http://www-cdf.fnal.gov/physics/ewk/2008/dszdy .

[9] DØ Collaboration, V. Abazov *et al.*, Phys. Rev. **D77**, 0111106(R) (2008).

[10] CDF Collaboration, D. Acosta *et al.*, Phys. Rev. **D71**, 051104 (2005).

[11] J. Pumplin em et al., JHEP **0207** (2002) .

[12] DØ Collaboration, V. Abazov *et al.*, hep-ex/0807.3367 (2008) .

[13] CDF Collaboration, http://www-cdf.fnal.gov/physics/ewk/2007/WChargeAsym/W_Charge_Asymmetry.html .