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DIJET MASS SPECTRUM AND DIJET AZIMUTHAL DECORRELATIONS MEASURED BY THE DØ EXPERIMENT AT THE TEVATRON

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Recent QCD results obtained from the Tevatron Run II data are reported. The DØ experiment at the Tevatron has used $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to measure the dijet invariant mass spectrum and the dijet azimuthal angle decorrelations.

1 Introduction

According to perturbative QCD (pQCD) at lowest order in the strong coupling constant, $\mathcal{O}(\alpha_s^2)$, jets in $p\bar{p}$ collisions are produced in pairs. In this approximation, the jets have identical transverse momenta, p_T , and correlated azimuthal angles, ϕ jet, with $\Delta\phi_{\rm dijet} = |\phi_{\rm jet\ 1} - \phi_{\rm jet\ 2}| = \pi$. Additional jets can be produced at higher orders and the two leading jets may be decorrelated with $\Delta\phi_{\rm dijet} < \pi$. The azimuthal decorrelation of the two leading jets is sensitive to additional radiation which manifests itself as additional p_T in an event. Soft additional radiation with $p_T \to 0$ results in $\Delta\phi_{\rm dijet} \to \pi$, whereas values of $\Delta\phi_{\rm dijet} \ll \pi$ are an indication of hard additional radiation. The measurement of the $\Delta\phi_{\rm dijet}$ distribution is thus an ideal testing ground for higher order QCD effects, without the experimental problems associated with reconstructing additional jets.

Measurements of the dijet production cross section as a function of the dijet invariant mass can be used to test QCD predictions for parton-parton scattering and to constrain the parton density functions (PDF) of the proton, particularly the gluon distribution. The increase in center-of-mass energy from 1.8 to 1.96 TeV is expected to bring a significant increase in the jet cross section at high p_T (by factor of 2 for dijet invariant mass $\approx$ 800 GeV) according to the NLO QCD prediction. With a data sample similar to that obtained in Run I, the DØ collaboration is able to measure jet production at much higher energies than those possible in the previous run.

2 Data Sample

The presented preliminary results from DØ are based on a data sample collected during the time period from August 2002 to September 2003 at the Fermilab Tevatron Collider at a center-of-mass energy $\sqrt{s} = 1.96$ TeV. The data sample represents an integrated luminosity of approximately 143 pb^{-1}. These data were collected using four inclusive jet triggers. Each trigger requires a localized energy deposited in the calorimeter and a reconstructed jet with p_T above one of the following thresholds: 25, 45, 65, or 95 GeV.

The jets are reconstructed in the DØ calorimeter using an iterative cone algorithm with $\Delta R = \sqrt{\Delta y^2 + \Delta\varphi^2} = 0.7$ [1]. The energy from the collision not associated with the hard scattering (underlying event energy) is subtracted from the total jet energy. The jet energy scale was defined using information from $\gamma+$jet events, low bias triggers, and Monte Carlo simulations. There are large statistical uncertainties and substantial systematic uncertainties in this energy scale determination that increase with energy due to extrapolation. These are principally caused by small $\gamma+$jet statistics above 250 GeV. This is the dominant systematic uncertainty in the dijet jet mass measurement. The jet measurements are restricted to the rapidity range $|y_{\text{jet}}| < 0.5$ to limit the impact of these uncertainties.

A primary vertex with at least 3 tracks and $|z_{\text{vtx}}| < 50$ cm is required to ensure a good jet energy measurement. The jet selection was based on calorimeter characteristics to reduce the number of misidentified jets. The data were corrected for the jet energy scale, selection efficiencies, and for migrations due to the p_T and position resolution.

3 Dijet Azimuthal Angle Decorrelations

The DØ collaboration measured the dijet cross section as a function of $\Delta\phi_{\text{dijet}} = |\phi_{\text{jet }1} - \phi_{\text{jet }2}|$, normalized by the inclusive dijet cross section, integrated over the same phase space. The measurement was made in four ranges of the leading jet $p_{T\text{ jet }1}$, starting at $p_{T\text{ jet }1} > 75$ GeV. The requirement for the second leading jet was $p_{T\text{ jet }2} > 40$ GeV.

The four plots in Fig. 1 show the $\Delta\phi_{\text{dijet}}$ distribution, in different regions of $p_{T\text{ jet }1}$, overlaid by the results of the NLOJET++ [3] NLO and LO pQCD calculations with the CTEQ6.1M PDF [2]. The renormalization and factorization scales were set to $\mu_r = \mu_f = 0.5 \cdot p_{T\text{ jet }1}$.

The phase space for the LO prediction with three final-state partons is limited to $\Delta\phi_{\text{dijet}} > 2\pi/3$ due to the requirement that $\Delta\phi_{\text{dijet}}$ is defined between the two leading jets. The LO prediction at $\Delta\phi_{\text{dijet}} \to \pi$ is dominated by the phase space where the third jet is soft ($p_{T\text{ jet }3} \to 0$). The LO prediction therefore diverges for $\Delta\phi_{\text{dijet}} \to \pi$. Only in the highest $p_{T\text{ jet }1}$ range the LO predictions give a fair description of the intermediate $\Delta\phi_{\text{dijet}}$ region.

The NLO predictions are in good agreement with the data in almost the whole kinematic range. These predictions only fail in the extreme regions at high-$\Delta\phi_{\text{dijet}}$ and at low-$\Delta\phi_{\text{dijet}}$ ($\Delta\phi_{\text{dijet}} < 2\pi/3$)

The limitations of fixed order pQCD at $\Delta\phi_{\text{dijet}} \to \pi$ can be improved by calculations that re-sum leading logarithmic terms to all orders in α_s. Monte Carlo event generators with parton shower models, such as PYTHIA and HERWIG [4], are good approximations to such re-summed calculations. Results from PYTHIA and HERWIG are compared to the data in Fig. 2. Also included in Fig. 2 is a PYTHIA calculation tuned to other $p\bar{p}$ scattering data ("tune A" from R. Field [5] based on data measured by the CDF collaboration [6]). The default versions of PYTHIA and HERWIG provide a better description of the data over the whole range of $\Delta\phi_{\text{dijet}}$

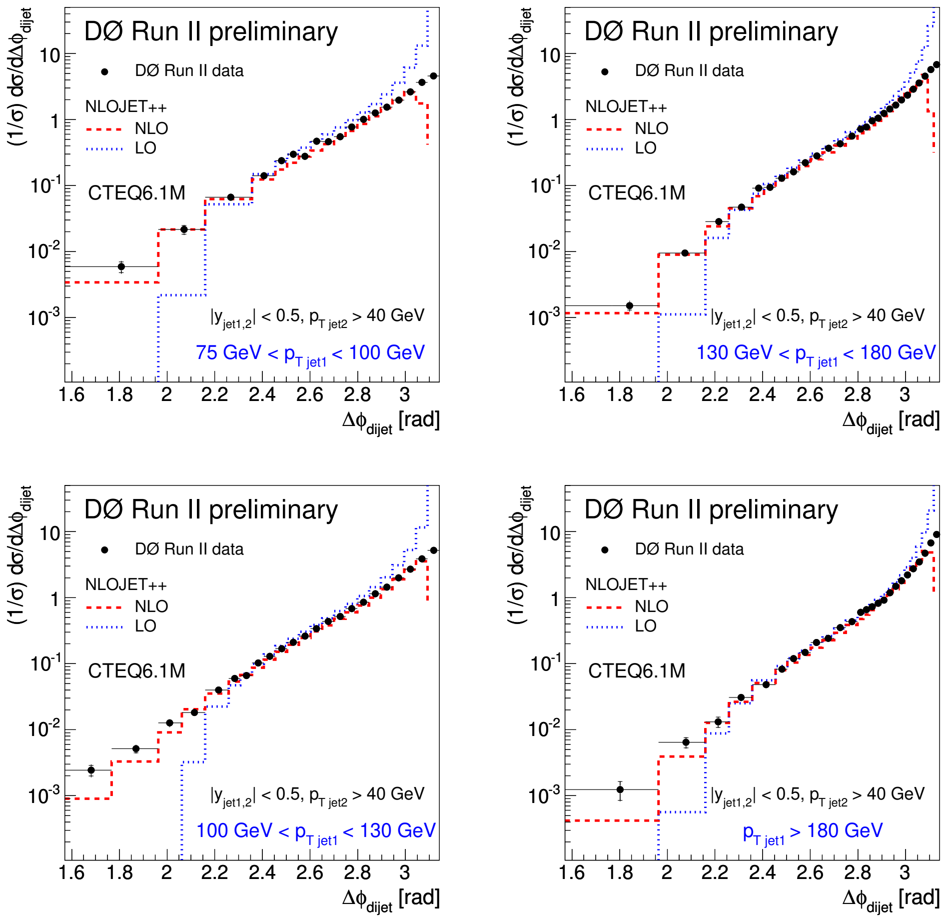


Figure 1. DØ dijet azimuthal decorrelation, $\frac{1}{\sigma_{\rm dijet}}\frac{d\sigma_{\rm dijet}}{d\Delta\phi_{\rm dijet}}$, measured in different regions of the leading jet $p_{T\ \rm jet\ 1}$. The LO and NLO pQCD predictions are compared to the data.

than LO pQCD. The description is substantially improved by using tuned PYTHIA parameters. However, in the intermediate $\Delta\phi_{\rm dijet}$ region the best description of the data is still obtained by NLO pQCD.

4 Dijet Invariant Mass Spectrum

The DØ collaboration measured the dijet cross section as a function of the dijet invariant mass. The size of the data sample, requirements for the events and the algorithm used for jet reconstruction are the same as for the inclusive jet cross section measurement.

The observed dijet differential cross section as a function of dijet mass is shown

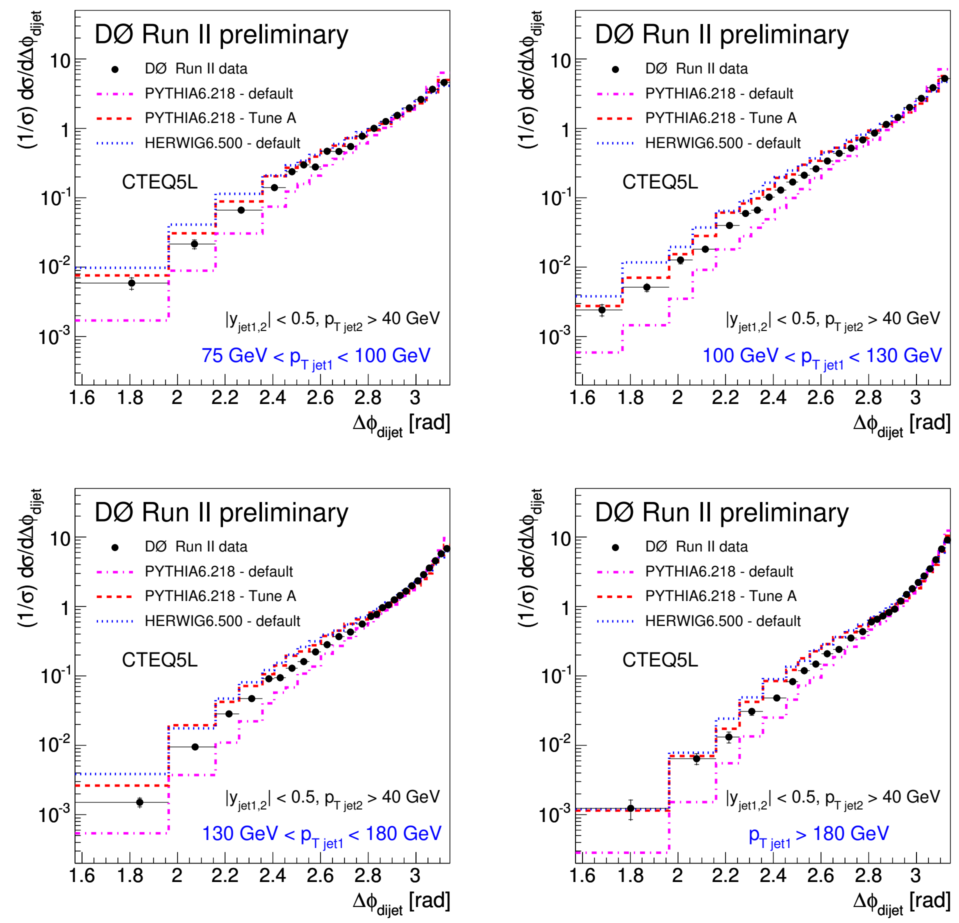
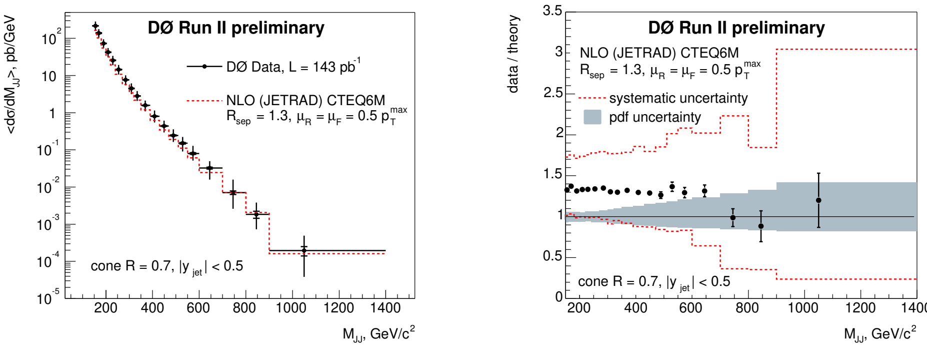


Figure 2. DØ dijet azimuthal decorrelation, $\frac{1}{\sigma_{\rm dijet}} \frac{d\sigma_{\rm dijet}}{d\Delta\phi_{\rm dijet}}$, measured in different regions of the leading jet $p_{T\ {\rm jet}\ 1}$. The predictions from PYTHIA and HERWIG are compared to the data. The PYTHIA results are shown for the default version and for a version tuned to other data from $p\bar{p}$ collisions.

in Fig. 3(a). The inner bars represent experimental statistical errors and the outer bars are systematic uncertainties. The 6.5 % luminosity error, which is correlated bin-to-bin, is not shown.

The observed cross section was compared with the results of a NLO pQCD calculation made with JETRAD [7] Monte Carlo generator using CTEQ6M [8] PDF. The factorization and renormalization scales have been set equal to $p_T/2$ of the leading jet in the event and $R_{\rm sep}$ has been set to 1.3. Linear comparisons of the calculation to the data are presented in Fig. 3(b). Within errors, there is an agreement with the theory.



(a) (b)

Figure 3. DØ dijet cross section as a function of dijet mass (a). The dijet cross section shown as (data – theory)/theory as a function of dijet mass, CTEQ6M PDF was used in the theory calculation.

5 Acknowledgments

It is a pleasure to thank all participants in the DØ collaboration for the extraordinary amount of effort that they have made to bring to reality the Winter 2004 measurements reported in these proceedings.

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