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NEW QCD RESULTS FROM THE TEVATRON

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This paper presents new results on jet cross sections, di-jet angular correlations, di-photon cross sections, W plus jet cross sections, studies of the underlying event, elastic scattering studies, and searches for diffractively-produced Z bosons for the winter 2004 conferences from up to 200 pb^{-1} of data taken at the $\sqrt{s}$=1.96 TeV at the Tevatron by the CDF and DØ collaborations.

1 Introduction

The Tevatron accelerator at Fermi National Accelerator Laboratory in Chicago Illinois was upgraded in 2000, the main addition being a new accelerator, the Main Injector. This and other accelerator upgrades will eventually allow instantaneous luminosities up to 10^{32} $s^{-1}cm^{-2}$. The accelerator, at the time of this conference, was running at about $0.6 \cdot 10^{32}$ $s^{-1}cm^{-2}$. The upgrade also increased the center-of-mass energy from 1.8 TeV to 1.96 TeV. The two Tevatron experiments, CDF and DØ have recently started taking physics-quality data, CDF since March 2002, DØ since November 2002. First results on QCD physics from this data were presented at the winter conferences in 2003. This paper presents new results on jet cross sections, di-jet angular correlations, di-photon cross sections, W plus jet cross sections, studies of the underlying event, elastic scattering studies, and searches for diffractively-produced Z bosons for the winter 2004 conferences from up to 200 pb^{-1} of data taken at the $\sqrt{s}$=1.96 TeV at the Tevatron by the CDF and DØ collaborations.

2 Jet Cross Sections

The measurement of the inclusive jet cross section is perhaps the best known QCD measurement from the Tevatron. In the past, this measurement has been used to probe the gluon distribution at large x and Q^2 (see for example Ref. [1]). The increased center-of-mass energy and integrated luminosity give increased reach in these variables. Both collaborations are also now using the same seeded, cone jet-finding algorithm, which is described in Ref. [2].

For this conference, CDF presented updated preliminary results on the cross section versus jet E_T for 177 pb^{-1} for the central region of their calorimeter $0.1 < |\eta| < 0.7$ and raw results, which have not yet been corrected for jet energy scale and energy smearing, for $0.7 < |\eta| < 2.5$. The results are shown in Figure 1. DØ presented corrected jet P_T spectra for $0.0 < |y| < 0.5$, $1.5 < |y| < 2.0$, and $2.0 <$

$|y| < 2.4$ using 143 pb^{-1}. Their results are shown in Figure 2. For both the CDF and DØ results, the leading uncertainty is jet energy scale. Both collaborations expect this uncertainty to decrease as the detectors are better understood.

DØ also presented a preliminary dijet mass spectrum. The result is shown in Figure 3. Again, the leading uncertainty is jet energy scale.

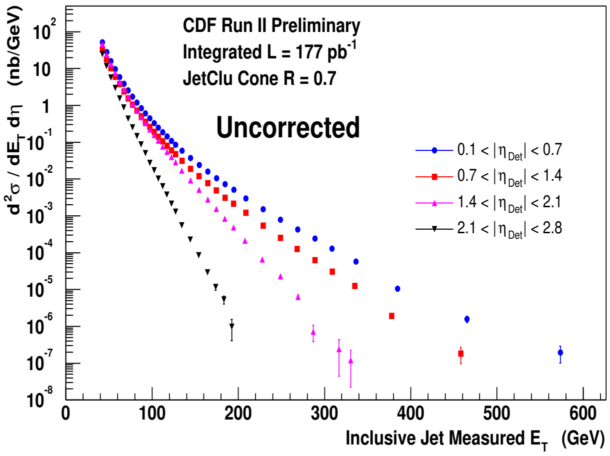

Figure 1. Preliminary jet E_T spectra from the CDF collaboration for $0.1 < |\eta| < 0.7$ and $0.7 < |\eta| < 2.5$. The central rapidity plot is corrected for jet energy scale and resolution effects, the forward rapidity plot is not.

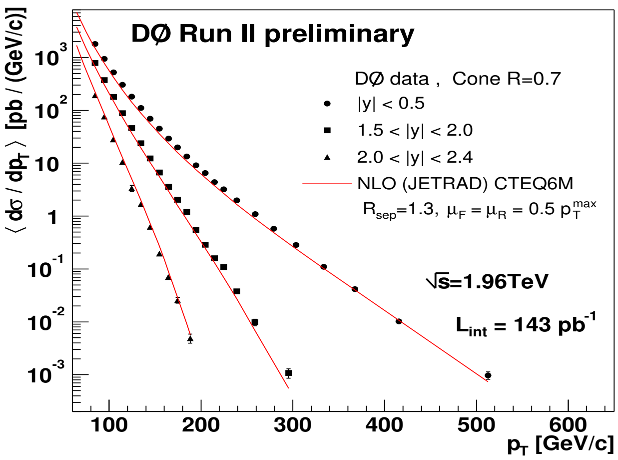

Figure 2. Preliminary jet P_T spectra from the DØ collaboration for three different rapidity intervals. All plots are corrected for jet energy scale and resolution effects.

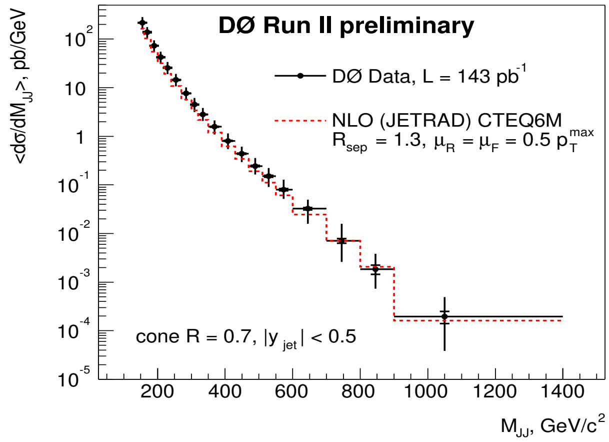

Figure 3. Preliminary dijet invariant mass distribution from the DØ collaboration, corrected for jet energy scale and resolution effects.

For more information, please see the talks at this conference by Alexei Safnov and Miroslav Kopal.

3 Di-jet Azimuthal Correlations

DØ presented a result on the opening angle in azimuth between the 2 leading jets in dijet events. At leading order, the jets are back-to-back. Thus, this distribution can be used to test higher order calculations of the properties of jet events. Another test would be to measure the properties of the third and fourth jets in the event. However, uncertainties on the jet energy scales are large for these low P_T jets. Tests using this distribution are independent of systematic errors from these sources. A similar distribution, the mean opening angle versus the absolute value of the difference in rapidity was published from Run I data [3]. However, this is the first time a differential distribution has been shown.

Figure 4 shows the preliminary results compared to two NLOJET++ [4]-based calculations, LO and NLO in the third jet. The agreement with LO is reasonable, except for very small and very large opening angles. The NLO agrees except at very small opening angles. The disagreement at large opening angles is caused by phase space, those at small because finite order calculations diverge in this region.

For more information, please see the talk at this conference by Pavel Demine.

4 Di-photon Cross Sections

CDF presented preliminary results on kinematic variables of inclusive di-photon events using 207 pb^{-1} of Run II data. Similar distributions have been published using Run I data [5]. At the time, there was a large discrepency between the data and the predictions of the NLO QCD calculation. However, the new calculations

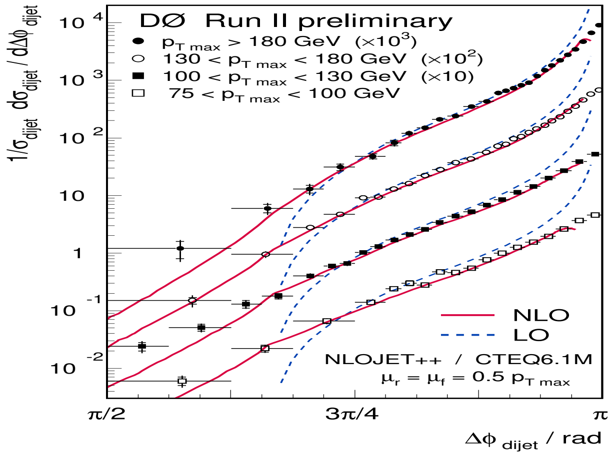

Figure 4. Preliminary spectra from DØ of the opening Angle between 2 leading jets in inclusive dijet events for a bin in the P_T of the leading jet, along with a prediction at LO and NLO in the third jet by the NLOJET++ program.

of Ref. [6] and [7], which are more complete the earlier NLO calculations, give good agreement with the new data. A comparision of the invariant mass of the 2 leading photons with these two calculations is shown in Fig. 5.

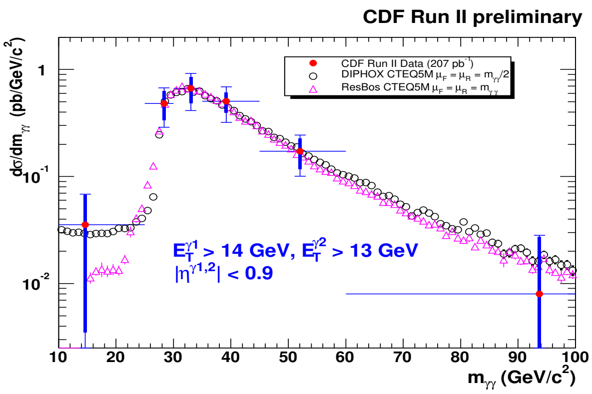

Figure 5. Preliminary spectra from the CDF collaboration of the invariant mass of the two leading photons in inclusive di-photon events, compared to NLO predictions.

5 W plus Jet Cross Sections

CDF also presented jet multiplicity distributions and kinematic distributions of the jets in $W \to e\nu$ events from 127 pb^{-1}. They find good agreement between the predictions for the jet multiplicity as well as kinematic variables such as the

E_T of the first, second, third, and fourth jet, the opening angle between the two leading jets, and the invariant mass of the two leading jets between the data and a calculation done using ALPGEN [8] at LO interfaced with HERWIG [9].

6 The Underlying Event

The CDF collaboration presented a preliminary study of minimum bias events and the underlying event in jet data. They use information from their tracking system, which is sensitive to charged particles with $|\eta| < 1.0$ and $P_T > 0.5 GeV/c$. They define an axis along the direction of the leading jet and look at the distributions of charged particles, such as $dN/d\eta d\phi$, relative to that axis. They do this for inclusive events and events containing at least 2 jets that are back-to-back in azimuth ($\Delta\Phi > 150^o$ and the ratio of the E_T of the leading jet to that of the second > 0.8). They find that the tune of PYTHIA done using Run I data still works well at the new center-of-mass energy. They also search for "mini jets" by looking at the distributions relative to the leading track in minimum bias events, or the leading track in the region transverse to the dijet axis in jet data. They find good agreement between the tuned PYTHIA for the jet data. There is some disagreement for the minimum bias data Many other similar distributions and comparisions were also presented. For more information, please see the talk at this conference by Niccolo Moggi.

7 Elastic Scattering of $p\bar{p}$

DØ presented preliminary results from their new Roman Pot system, that was installed during the shutdown to upgrade the Tevatron. One of the goal for this system is to measure the cross section versus t, which is defined as $(P_{beam} - P_F)^2$ where P_F is the final momentum of the scattered proton and is proportional to θ^2, the scattering angle of the proton squared. DØ presented preliminary data on this measurement. The normalization for the cross section is still not available, but the data show that the slope of the cross section versus t is consistent with expectations from lower energy experiments.

For more information, please see the talk at this conference by Tamsin Edwards.

8 Diffractive Z's

DØ also presented a preliminary search for diffractively produced Z bosons. Diffractive Z's could be identified by looking for events which have very little energy in the region of the calorimeter near either the outgoing direction of the p or $\bar{p}$, indicating that it remained intact after the interaction that produced the Z. CDF [10] published results on this using the Run I data and DØ published both diffracive Z and diffractive W [11] results. but the results seemed inconsistent. While the results before the correction for the gap-finding efficiency seem similar, after correction they are quite different. The new data is taken at higher luminsosity, which will reduce the gap-finding efficiency and increase the challenge of doing the measurement. DØ presented plots that show evidence of gaps in the new $Z \to \mu^+\mu^-$ data;

whether or not this is due to diffraction is still under investigation and remains to be verified..

For more information, please see the talks at this conference by Koji Terashi and Tamsin Edwards.

9 Conclusions and Future Prospects

The Tevatron has been running since 1988. Using the approximately 150 pb^{-1} taken at $\sqrt{s}$ =1.8 TeV taken prior to Run II, the Tevatron collaborations published over 84 papers on QCD excluding the many publications on QCD with b quarks. The experiments now finally have understood their detectors well enough to start publishing results from the Run II data. The new data allows higher reach in x; progress in QCD theory allow more refined interpretations of the data. Publications should start to appear this summer. The HEP community can expect many publications from this and future data, over the coming years.

Acknowledgements

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