Jet and Photon Physics at DØ

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We report several new DØ measurements related to issues in QCD. Because of its large reach in x-Q^2 and due to a thorough analysis of correlated systematic errors, the rapidity-dependent inclusive jet cross section has had a significant impact on the extraction of parton distribution functions. The ratios of jet and photon production at $\sqrt{s} = 1800$ and 630 GeV, although in general agreement with theory, indicate that not all aspects of these processes are fully understood. Studies of multiple jet production at moderate and low E_T values have provided means to explore QCD scales and to tune the related aspects of event generators. A definitive signal for diffractive production of W bosons has been established, providing a new probe of the quark structure of the Pomeron. And, following on a great effort to bring up the experiment after a long shut-down and extensive upgrades, DØ is accumulating and analyzing new data at 2 TeV. The preliminary results for inclusive jet p_T and dijet mass spectra are just the first steps in exploiting the opportunities that Run II of the Tevatron will provide.

Within the framework of perturbative QCD (pQCD), hard-scattering processes are described by a convolution of partonic cross sections with the parton distribution functions (PDFs). Thus, measurements of high p_T interactions constrain PDFs, test current phenomenology, and provide opportunities to search for deviations from pQCD (*e.g.*, parton compositeness).

The hard-scattered quarks and gluons in the final state fragment into jets of particles that subsequently interact in the detectors. Experimentally, jets are usually defined by their energy deposition in multiple calorimeter towers. The jet results reported here employ the iterative fixed-radius cone algorithm, with $R = 0.7$ in η-ϕ space. While Run-I jets consist of E_T-weighted sums of calorimeter towers, in Run II jets are defined by 4-momentum sums of the towers inside the cone, and midpoints between such jets are used as additional seeds for the algorithm in order to ameliorate sensitivity to infrared divergence of gluon radiation [1]. Production of objects at low and moderate p_T is sensitive to fragmentation, multiple parton interactions, and to the remnants of the colliding particles not participating in the hard collision. Studies of these effects help develop phenomenological descriptions of such soft physics and in the tuning of event generators.

The high-x behavior of PDFs has been discussed intensely for the past several years. DØ measurement [2] of the inclusive jet cross section in 5 different η regions, shown in Fig. 1, has provided powerful new information. The large coverage of parton phase-space results in unprecedented sensitivity to PDFs, and the evaluation of the correlated errors among the 90 experimental points permits a more rigorous incorporation of the data into recent global determinations of PDFs by the CTEQ [3] and MRST [4] groups. DØ jet data have been included in these fits without extra weight applied to their contribution to the total χ^2; the resulting gluon PDFs show a significant enhancement at large x over previously available best fits. The data are described very well by NLO QCD calculations using these new PDFs (see Fig. 2 for the CTEQ6M result).

The ratios of jet and photon measurements at $\sqrt{s}$ of 630 and 1800 GeV have been studied to investigate the scaling of the cross section with energy. Various experimental and theoretical uncertainties tend to cancel in the ratio. The ratio of the dimensionless central jet cross sections vs $x_T = 2E_T/\sqrt{s}$ is shown in Fig. 3. The 10-15% disagreement in normalization between data

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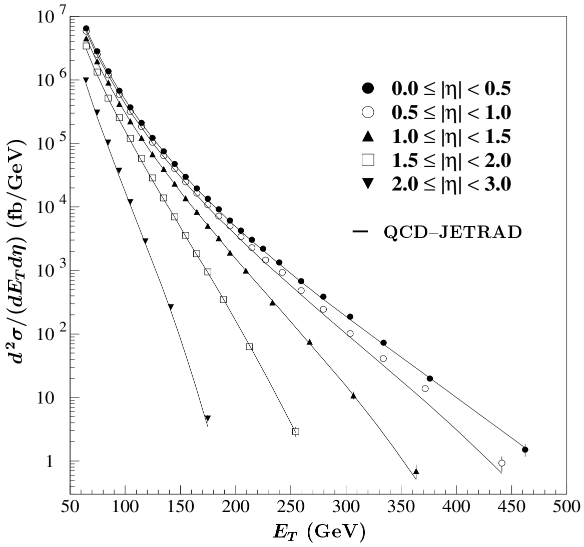

Figure 1. The inclusive jet cross section vs E_T, for 5 bins of $|\eta|$, compared to JETRAD calculation with the CTEQ4M PDF.

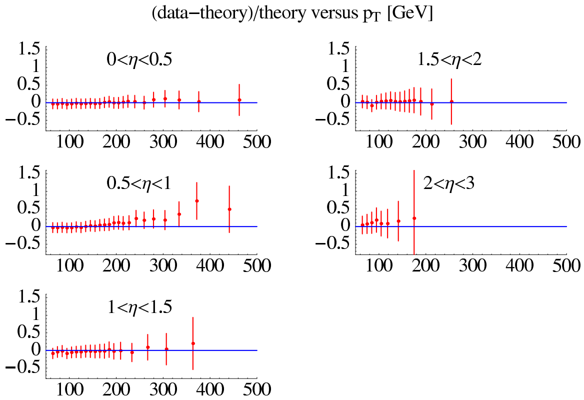

Figure 2. Comparison of jet data to NLO calculation using CTEQ6M PDF; $\chi^2 = 65$ for 90 points.

and theory, as well as some difference in shape, can not be accommodated through varying the choice of PDFs or of the pQCD scales [5]. Other explanations have been proposed, *e.g.*, invoking low-E_T non-perturbative effects, or using different scales at the two $\sqrt{s}$. The analogous ratio for direct-photon production [6] is shown in Fig. 4. The data are in overall agreement with NLO QCD, with possible deviation at lowest x_T values. However, current sensitivity is not sufficient to either prove or disprove the proposed presence of dynamic parton k_T effects in photon production at these energies [7]. Run II measurements should shortly provide additional information to help clarify these issues.

The measurement [8] of the ratio of inclusive three-jet to two-jet production, R_{32} vs $H_T = \sum E_T^{\rm jet}$, reflects the rate of gluon emission in the jet production. The data were compared to predictions from JETRAD using different renormalization scales for the third jet (Fig. 5). No evidence was found to indicate the need to introduce such a separate scale. The common scale $\approx 0.3 H_T$ describes the data satisfactorily.

DØ has recently performed a study of multiple jet production at low $E_T \approx 20$ GeV [9]. This process is expected to be sensitive to soft gluon emission and multiple-parton scattering effects. The data were compared to the predictions from PYTHIA 6.127 and HERWIG 5.9 (and with JETRAD for certain aspects). A good description of the results has been obtained after tuning parameters in the generators (PARP(83)=0.32 in PYTHIA and PTMIN=3.7 in HERWIG), as shown in Fig. 6, but the "off-the-shelf" versions with the default values disagree with the data.

DØ is completing an investigation of diffractive production of W and Z bosons using Run I data [10]. Since electroweak bosons couple only to quarks (at lowest order), this process facilitates examination of the quark structure of the Pomeron [11]. By using the rapidity-gap technique, a definitive signal for diffractive W boson production was established with 91 candidate events; diffractive Z boson production was observed for the first time, with only 9 candidate events. These data provide preliminary measurements of the diffractive component $R_W = 0.89^{+0.20}_{-0.19}\%$ and $R_Z = 1.44^{+0.62}_{-0.16}\%$ of total W and Z boson production, respectively. For Run II, DØ has installed Roman-pot detectors to tag protons and antiprotons in the final state. In particular, this will allow a direct measurement of the quark-gluon structure of the Pomeron, and to study for

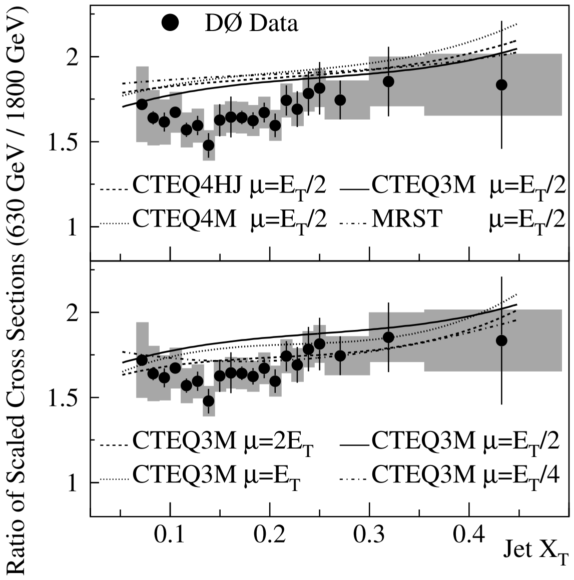

Figure 3. Ratio of jet cross sections at $\sqrt{s} = 630$ and at 1800 GeV, vs x_T, compared to calculations with different PDFs and variations of pQCD scales.

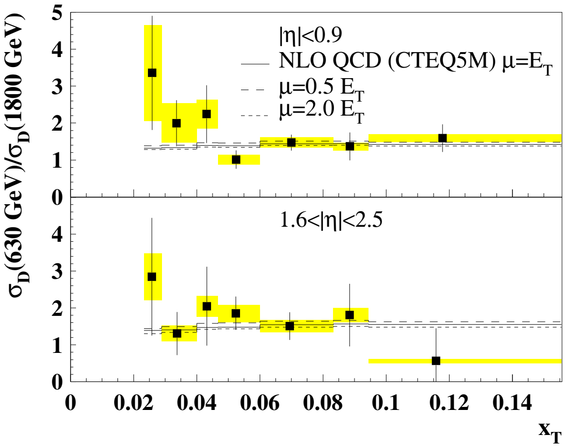

Figure 4. Ratio of photon cross sections at $\sqrt{s} =$ 630 and at 1800 GeV, vs x_T.

the first time the double Pomeron exchange.

After extensive upgrades of virtually all subsystems of the detector, DØ is collecting physics-quality data from Run II of the Fermilab Tevatron. High-p_T jet production at $\sqrt{s} = 2$ TeV is the highest-priority measurement for the ultimate determination of the gluon PDF, and the search for new physics at shortest distance scales. In addition to the much larger integrated luminosity expected in Run II, jet measurements at $\sqrt{s} = 2$ TeV also benefit from a cross section increase by factors ≥ 2 (at largest p_T) relative to Run I. Figures 7 and 8 show the preliminary jet inclusive and dijet mass spectra derived from ≈ 6 pb^{-1} of data taken during March–May 2002. Although the analyses are well under way, the displayed results have not yet been fully corrected for experimental effects, so comparisons to theory would be premature. The limited η range is due to the fact that Level-1 jet triggers were constrained to $|\eta| < 0.8$ during that period (this range has now been expanded significantly).

The large kinematic reach of jet measurements in Run II is already apparent. Improvements in the precision of the results are anticipated thanks to the upgraded detectors, and the NNLO calculations are expected to be available shortly. We are entering an important period for studies of QCD.

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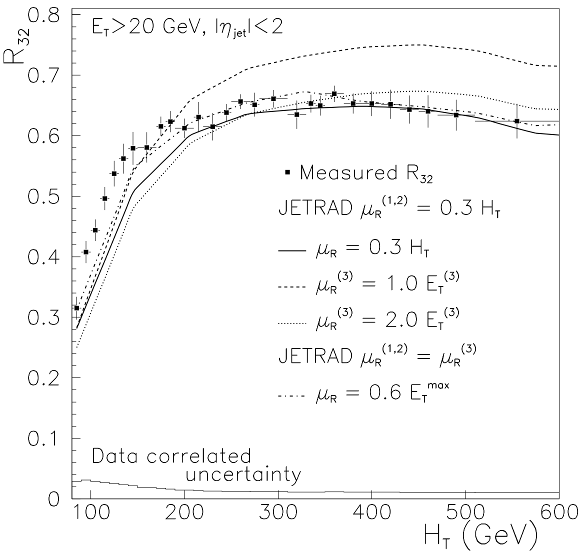

Figure 5. Ratio of $\geq$ 3-jet to $\geq$ 2-jet production vs H_T, compared to JETRAD calculations with various scales.

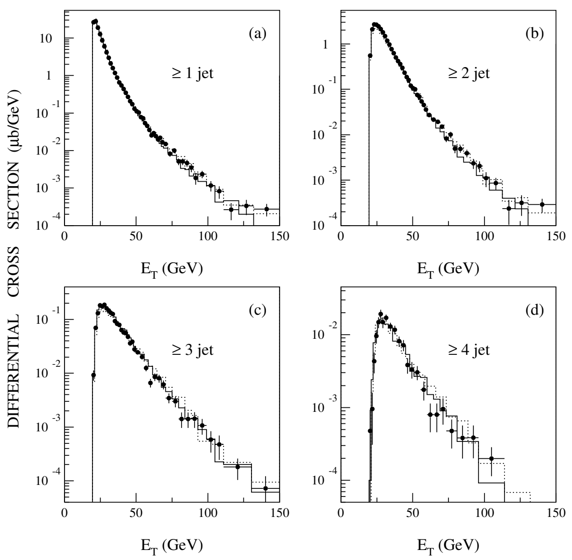

Figure 6. Leading jet E_T for multiple inclusive jet production, compared to predictions from PYTHIA (solid) and HERWIG (dotted).

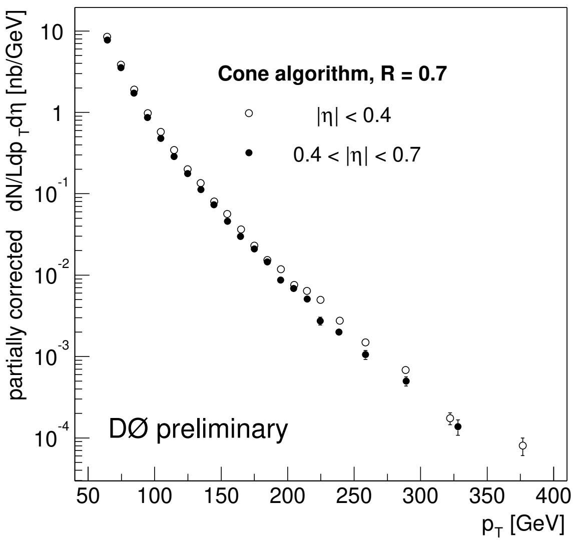

Figure 7. Inclusive jet-p_T spectra in Run II data.

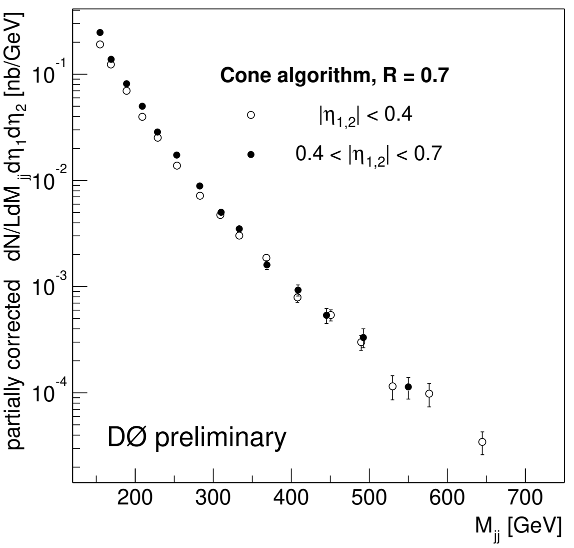

Figure 8. Dijet mass spectra in Run II data.