FERMILAB-CONF-09-693-E

HIGH P_T JETS AND PHOTONS AT DØ

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We present QCD related results from the DØ Experiment at the Fermilab Tevatron Collider. A data sample corresponding to an integrated luminosity of up to 1 fb^{-1} is used in various measurements. Processes with high transverse momenta jets or photons are compared with NLO QCD calculations using the PDF input functions. These results can be used to further improve the knowledge of proton structure.

1. Introduction

As of winter 2008, both the CDF and DØ experiments at the Fermilab Tevatron Accelerator collected each about 3 fb^{-1} of luminosity. Their physics programs cover electroweak and strong sectors of the Standard model, searches for the Higgs boson as well as searches for any new physics. The latest tests of Quantum chromodynamics (QCD) performed by DØ are presented. These measurements utilize a precise jet energy calibration which allowed significant reduction of experimental uncertainties.

2. DØ Experiment

The DØ detector is described elsewhere.[1] It is a multipurpose detector with design similar to other collider experiments. The interaction region is surrounded by a tracking detector consisting of a silicon microstrip detector and a fiber tracker. The liquid argon/uranium calorimeter behind the tracking system measures the energy of most particles. The calorimeter is surrounded by three layers of muon detector.

2.1. *Jet Reconstruction and Jet Energy Scale*

Jets (clusters of hadrons) are reconstructed using the RunII midpoint cone algorithm[2] with 0.7 cone radius. The jet energy scale calibration[3] corrects the jet fourmomentum to the level the jet had before entering the detector. It tries, on average, to remove all detector and accelerator effects like multiple interactions in the same bunch crossing, pile-up in the detector from previous interactions, response of the calorimeter to hadronic particles and showering effects due to the jet algorithm. DØ has extensively characterized all these effects and additional biases between them. The basic formula for the correction is

$$E_{\rm jet}^{\rm corrected} = \frac{E_{\rm jet}^{\rm measured} - O}{R \cdot S} \cdot k_{\rm bias}, \tag{1}$$

where O is the offset correction which subtracts additional energy coming from multiple interactions in the same proton antiproton bunch crossing and energy coming from pile-up. Response R of the calorimeter to hadronic jets is measured using a special sample of photon plus jet events where a (calibrated) photon is balanced by a jet on the opposite side. In order to increase statistics in the forward region, dijet events with one jet in central calorimeter are used. The showering correction S corrects for effects of particle shower development in the calorimeter and $k_{\rm bias}$ contains other additional biases.

The uncertainty on the correction factor (ratio of uncorrected to corrected energy) is displayed in Fig. 1 for central and forward jets. The achieved precision improves significantly the previous calibrations at hadron colliders and substantially reduces the experimental errors on jet measurements. It should be noted that the expected jet energy calibration precision during early running of the LHC is about 5–10%.

3. Inclusive Jet Cross Section

A measurement of the production cross section of high $p_{\rm T}$ jets is an important test of QCD predictions of the structure of proton and its dynamics. An excess of high $p_{\rm T}$ jets can be a sign of new physics like quark substructure.

The cross section for a general QCD process can be written as

$$\sigma(p\bar{p} \to X) = \sum_{a,b} \iint {\rm d}x_1 {\rm d}x_2 f_{a/p}(x_1) f_{b/\bar{p}}(x_2) \sigma(a+b \to c+d) \otimes C_{\rm had}, \tag{2}$$

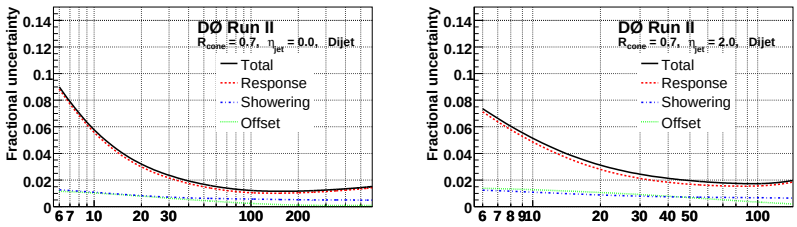

Figure 1. Final DØ jet energy scale uncertainty for central (left) and forward (right) jets.

summing relevant partonic processes which contribute to production of X, and integrating over available kinematic region.

The inclusive jet cross section is measured as a function of jet transverse momentum in six bins of jet rapidity. The maximum reach of jet transverse momentum is about 600 GeV. The integrated luminosity of the dataset used in this measurement is 0.70 fb^{-1}. Data is corrected for detector and trigger inefficiencies and then compared with next-to-leading (NLO) order QCD predictions of FASTNLO[4] program based on NLOJET++[5] using the latest parton distribution functions (PDF) CTEQ6.5M[6] and MRST2004[7].

The data are found to be in a good agreement with NLO QCD predictions over the whole range of phase space. At the high p_{T} end of the spectra, they tend to favor the lower edge of the PDF error band. The significantly reduced experimental uncertainty allows inclusion of this measurement into the next iterations of PDF measurements. Correlations between systematic uncertainties are also available.[8]

4. Triple Differential Photon Plus Jets Cross Section

Photons (and other vector bosons) can also be produced in association with jets. The advantage of directly produced photons is that they do not undergo the hadronization process. The theoretical computation then does not need additional non-perturbative corrections since the photon detected is the same photon which emerged from the parton scattering. On the other hand, direct photons must be separated from a background photons coming from hadron decays (for example $\pi^0 \to \gamma\gamma$) and from quark bremsstrahlung. DØ has measured a cross section for direct photon production[9] and extended it with a triple differential photon plus jet cross section.[10]

In this measurement, the cross section is measured differentially as a

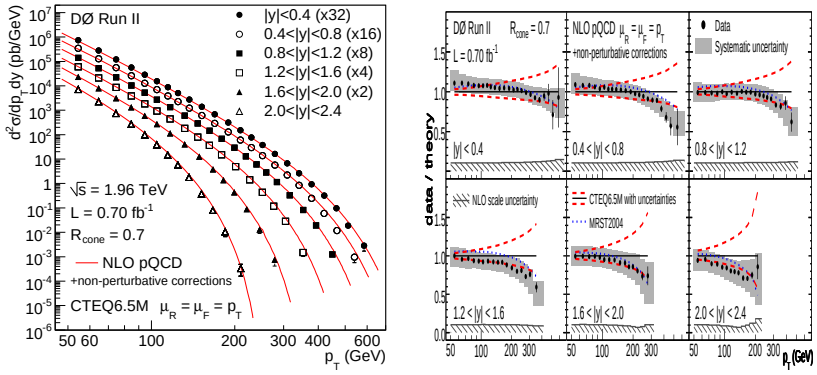

Figure 2. Inclusive jet cross section $\sigma(p\bar{p}) \rightarrow \text{jet} + X$ in six bins of rapidity compared to NLO QCD prediction (left). Data to theory ratio showing statistical and systematic uncertainties and comparison with different PDF sets (right).

function of photon transverse momentum, photon rapidity and jet rapidity. Four regions are chosen (central calorimeter photon + central calorimeter jet and central calorimeter photon + forward calorimeter jet, both with photon and jet either on the same side or opposite side of the calorimeter (in rapidity)). Different regions have different kinematic reach (in terms of x_1, x_2 variables of the initial partons) and are therefore directly sensitive to different regions of PDFs.

The NLO QCD prediction provides only a fair description. Variations of renormalization and factorization scales can improve the agreement between data and theory, however this can not be done consistently in all four regions where the measurement is presented.

5. Conclusions

Larger dataset and improved jet energy scale calibration allow more precise comparisons between experimental data from the DØ experiment and predictions of perturbative Quantum chromodynamics. This data improves our knowledge about the proton structure and has particular importance with the anticipated start of the Large Hadron Collider at CERN later in 2008, which will be sensitive to new physics currently unavailable.

The inclusive jet cross section measurement presented here is in agreement with the next-to-leading order prediction and can be used to further constrain the parton distribution functions. The theory fails to consistently describe the triple differential photon plus jet cross section.

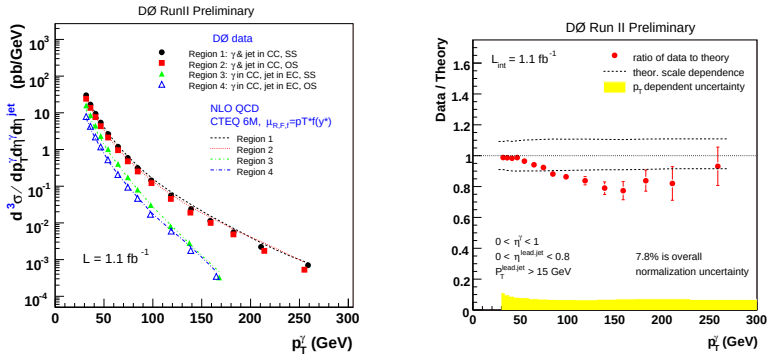

Figure 3. Triple differential photon plus jets cross section - four different regions (central calorimeter photon with either same side (SS) or opposite side (OS) jet in central (CC) or end cap (EC) calorimeter) compared with NLO QCD predictions (left). Data to theory ratio in the region with central calorimeter jet on the same side of rapidity as a photon (right).

Acknowledgments

The work was supported by the grant MSM 6840770039 of the Czech Ministry of Education.

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