Jet Measurements at DØ*

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The goal of the student's talk was to present all stages of any jet measurement from data collection to comparison of experimental results with theoretical predictions. All experimental examples were taken from the DØ experiment at Fermilab Tevatron collider.

1. Introduction

SLAC experiments in the late sixties led to the development of parton model [1] in which protons (as well as other hadrons) consist of smaller constituents identified with quarks and gluons in Quantum Chromodynamics(QCD). Later searches for free partons were not successful and it was QCD which described why. Instead of individual partons only hadrons can be observed as a result of a process called hadronization. The idea which enables to study the original partons is that hadronization should be a soft process which does not significantly change their original properties and that the final state hadrons carry the momenta of the interacting partons. The conclusion of this idea is that one should observe localized cluster of particles in a few distinguished directions of the partons. These clusters are called jets.

2. Jets

Localized clusters of energy or jets were soon confirmed by experiments [2] and it became evident that the cross section for jets production can be computed with perturbative QCD. It required improvements on both experimental and theoretical side in terms of jet definition.

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2.1. Jet Algorithms

The tool which finds jets among a few partons in theoretical calculations as well as among hundreds of calorimeter cells in experimental data is called jet algorithm. There are two common types of jet algorithms which are used to cluster particles into jets. More common in lepton-lepton and lepton-hadron collisions is the class of k_T algorithms. In this algorithm, particles are iteratively paired together if they obey satisfy some condition (for example their relative p_T with respect to each other is smaller than some defined scale). More common in hadron-hadron collisions are cone algorithms. In these algorithms, particles are clustered into one jet if they lie within some geometrical boundary (cone with radius R) DØ uses the so-called RunII Midpoint cone algorithm which properties are specified in [3] with radii $R = 0.5$ and $R = 0.7$. The main requirement on the algorithm is its infrared and collinear safety. The algorithm must be insensitive to radiation of soft particles since they will become indistinguishable due to experimental resolution. If a final state with the emission of soft or collinear particles leads to different number of jets than the state without them, the algorithm is not safe and it can not be used to make reliable predictions.

2.2. Jet Energy Calibration

In order to compare experimentally detected jets with theoretical computation, their energies must be corrected for various effects. At DØ, calorimeter jets are corrected to particle level (detector effects are corrected) while parton jets from theoretical computation are corrected to particle level too (using simulation of hadronization properties). Detector effects correction is parameterized as $E_{\text{jet}}^{\text{particle}} = (E_{\text{jet}}^{\text{calorimeter}} - \text{Offset})/(\text{Response} \cdot \text{Showering})$. The offset correction includes corrections for underlying event (soft part of the proton-antiproton interaction), calorimeter noise and pile-up from previous interactions in the detector. Response to jets is measured in central calorimeter in clean photon + jets events where jet is balanced with photon which response is properly calibrated in the electromagnetic part of DØ calorimeter using $Z \rightarrow e^+e^-$ decay. For forward calorimeter calibration, dijet events where one jet is in central and the other one in forward calorimeter are used. Showering corrects for the effect where part of the jet energy leaks out of the cone because of the calorimeter segmentation. Each of the subcorrections was independently studied to determine its dependence on other parameters like instantaneous luminosity, number of additional soft interactions etc. The total uncertainty of the jet energy calibration is shown in Fig. 1.

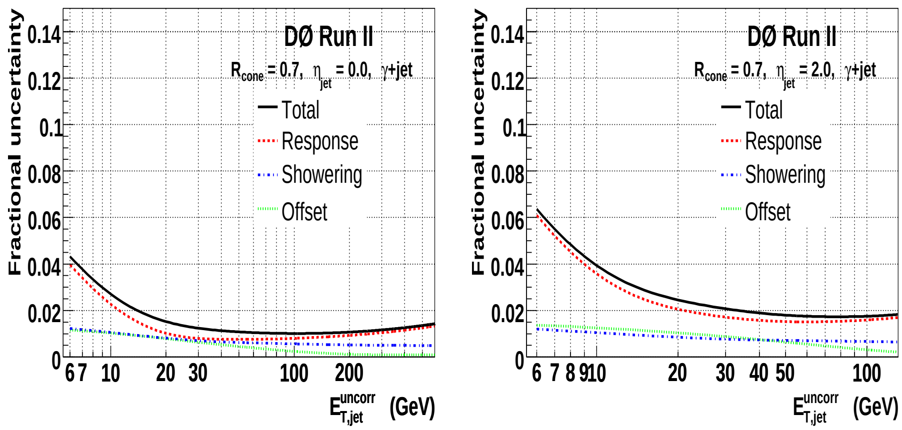

Fig. 1. Jet energy scale fractional uncertainty for 0.7 cone jets for central (left) and forward (right) calorimeter.

3. Jet Measurements

Calibrated jets can be then compared with theoretical predictions. This relies on the QCD theorems that the cross sections can be factorized into separated soft and hard contributions. The hard part (large momentum transfers) is then computed using the knowledge of parton-parton interaction matrix elements (for example at next-to-leading order in perturbative QCD) convoluted with the parton distribution functions (PDFs) which describe the momentum distribution of partons in hadrons.

3.1. Inclusive Jet Cross Section

Inclusive jet cross section $p\bar{p} \to \text{jet} + X$ is measured at $\sqrt{s} = 1.96$ TeV using the DØ detector. The measurement is done in six rapidity regions; the maximum reach in jet transverse momentum is about 600 GeV. It uses part of the data collected with the DØ detector in RunII between 2002 and 2006. The total luminosity of the data is 0.7 fb^{-1}. The jets are corrected for detector and trigger inefficiencies and the results are compared with next-to-leading order predictions from NLOJET++ program[7] using the latest parton distribution functions CTEQ6.5M[8].

3.2. Isolated Photon Production

Isolated photons (or other vector bosons) can be also produced in association with jets. The perturbative QCD computation involves the same steps

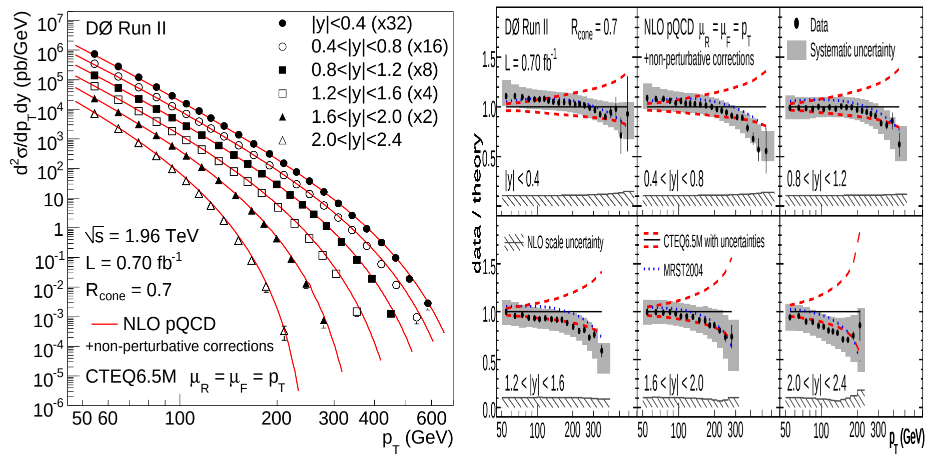

Fig. 2. Inclusive jet cross section $p\bar{p} \rightarrow$ jet + X in six bins of rapidity (left) and ratio of data to theory with systematic, PDF and scale uncertainties (right).

but photons have the advantage that they do not undergo the hadronization process. The observed photon is the same photon which emerged from the parton scattering. On the other hand, this isolated photons must be distinguished from photons coming from hadron decays (like $\pi^0 \rightarrow \gamma\gamma$). DØ measured the isolated photon cross section[9] and extended it with the cross section of photon production in association with a jet (Fig. 3).

4. Summary

After the definition of jets and their proper energy calibration, the experimental data are confronted with the latest theoretical computation. The measurement of the inclusive jet cross section is found to be in good agreement with the next-to-leading order perturbative QCD prediction and can be further used to constrain the parton distribution functions which is necessary for searches for physics beyond the standard model either at the Tevatron or in the future at the Large Hadron Collider. The photon measurements provide only fair agreement with the theoretical calculations.

5. Acknowledgment

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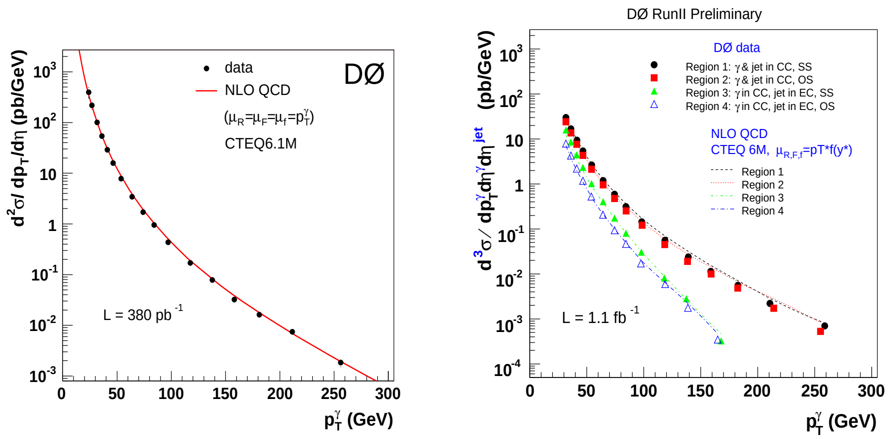

Fig. 3. Isolated photon cross section(left) and photon+jet cross section(right) measured with jet and photon on the same side (SS) and opposite side (OS) of the central (CC) and forward (EC) calorimeter.

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