PROCEEDINGS OF SCIENCE

Results from D0: dijet angular distributions, dijet mass cross section and dijet azimuthal decorrelations

Zdenek Hubacek

Czech Technical University in Prague
E-mail: zdenek.hubacek@cern.ch
on behalf of the D0 collaboration

Several tests of Quantum chromodynamics (QCD) in the inclusive dijet final state from the D0 experiment at the Fermilab Tevatron Collider are presented.

XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects
April 19 -23, 2010
Convitto della Calza, Firenze, Italy

PoS(DIS 2010)113

1. Introduction

At hadron colliders, jet production has one of the highest cross section and is therefore an ideal place to test the predictions of perturbative Quantum chromodynamics (pQCD). The difference in the azimuthal angle of the two jet system ($\Delta\phi$), the χ_{dijet} variable related to the polar angle of the dijet system ($\chi_{\text{dijet}} = \exp(y_1 - y_2)$, where $y_{1,2}$ are the rapidities $y = 0.5\ln(E + p_z)/(E - p_z)$ of the two jets, E is the jet energy and p_z is the jet momentum along the beam line) and dijet invariant mass M_{jj} are presented.

2. Data Selection

The analyses use a subsample of data collected in Run II by the D0 detector at the Fermilab Tevatron Collider. The detailed detector description is given in [1]. The dijet azimuthal decorrelations measurement uses approximately 150 pb^{-1}, while the dijet angular distributions and dijet invariant mass use about 700 pb^{-1}. Data sample is chosen using either inclusive jet triggers with several p_T thresholds or dijet mass triggers. Triggers are generally used in regions where they are at least 99% efficient. Events are chosen if they have at least two jets which satisfy event and jet quality cuts.

3. Dijet Azimuthal Decorrelations

In this measurement [2], the azimuthal angle between the two jets with the highest transverse momentum is studied, binned in four bins of the highest jet transverse momentum. In the absence of any radiation, the dijet production in hadron–hadron collisions results in two jets with equal transverse momenta and the difference between the azimuthal angles of the two jets is $\Delta\phi = \pi$. Additional soft radiation causes small azimuthal decorrelations while for the hard emission of the third jet $2\pi/3 < \Delta\phi < \pi$. Smaller values of $\Delta\phi$ require additional radiation such as a fourth jet. Therefore, the study of the $\Delta\phi$ distribution provide a test of higher order pQCD predictions without explicitely measuring the additional jets.

The analysis measures the $(1/\sigma)(d\sigma/d\Delta\phi)$ observable in four regions with transverse momentum of the leading jet $p_T^{\text{max}} > 75, 100, 130$ and 180 GeV. The second leading jet is required to have $p_T > 40$ GeV and both jets are required to be in the central region of the calorimeter ($|y| < 0.5$).

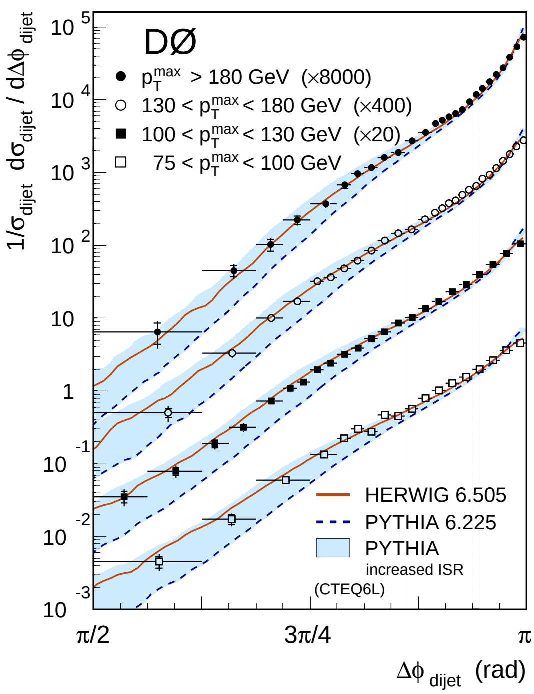

Figure 1: Dijet $\Delta\phi$ distributions in four ranges of the leading jet p_T compared to the predictions of HERWIG and PYTHIA generators.

The unsmearing correction for migrations between the bins due to detector resolutions were derived from events generated with HERWIG and PYTHIA. The angular resolution was determined from the full D0 detector simulation and was found to be better than 20 mrad. The jet transverse momentum resolution decreases from 18% at $p_T = 40\,\text{GeV}$ to 9% at $p_T = 200\,\text{GeV}$. The size of the correction is typically less than 8% for $\Delta\phi > 2\pi/3$ and $\sim 40\%$ for $\Delta\phi \sim \pi/2$. The jet energy scale uncertainty is still the dominant uncertainty of the measurement (7% for $\Delta\phi > 5\pi/6$ but up to 23% for $\Delta\phi < 2\pi/3$).

Monte Carlo generators like HERWIG and PYTHIA use LO $2 \rightarrow 2$ matrix elements and parton shower models to simulate the higher order contributions. The comparison with the default settings of the generators and CTEQ6L PDFs with the data is shown in Fig. 1. HERWIG describes the distribution well over the entire range, while in PYTHIA the variation from the default value in the maximum allowed virtuality of the initial state parton shower is needed.

4. Dijet Angular Distributions

In the dijet angular distribution measurement [3], the difference between the rapidities of the two jets with the highest transverse momenta is measured as this could be potentially sensitive to new physics models. We investigate the $\chi_{\text{dijet}} = \exp(y_1 - y_2)$ variable, where y_1 and y_2 are the rapidities of the two jets with the highest transverse momentum in the event in ten regions of the dijet invariant mass M_{jj}. The variable is in the case of massless $2 \rightarrow 2$ scattering directly related to the polar scattering angle θ^* by $\chi_{\text{dijet}} = (1+\cos\theta^*)/(1-\cos\theta^*)$ and is motivated by the fact that the Rutherford scattering is independent of it. The phase space of the analysis is constrained to $M_{jj} > 0.25\,\text{TeV}$, $\chi_{\text{dijet}} < 16$ and $y_{\text{boost}} = 0.5|y_1 + y_2| < 1$. Based on the measurement, we set limits on quark compositeness, ADD large extra dimensions and TeV^{-1} scale extra dimensions.

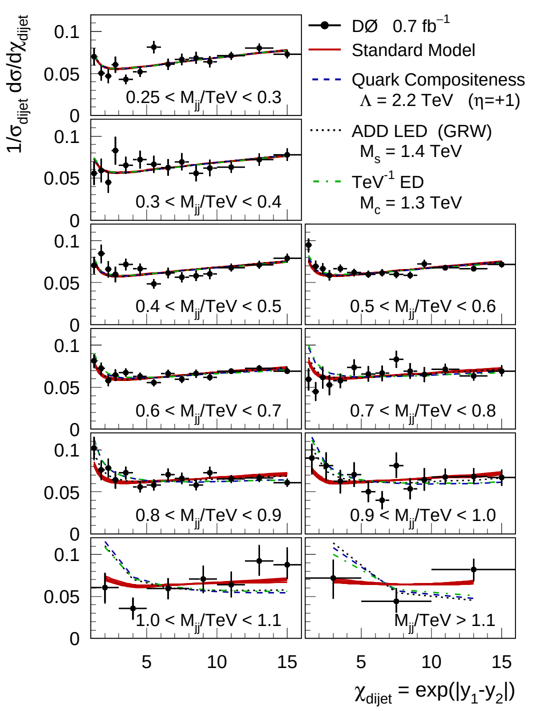

Figure 2: χ_{dijet} distribution compared with Standard Model (NLO pQCD) and several new models predictions.

The χ_{dijet} distributions are corrected for detector effects using events generated with PYTHIA v6.419 using tune QW and MSTW2008LO PDFs which are run through a fast detector simulation which includes parameterizations of transverse momentum and angular resolutions as well as other jet reconstruction efficiencies and misidentification of the event vertex. The total detector corrections are usually between 0.9 and 1.0 and always between 0.7 and 1.1. The dominant systematic uncertainties are from the jet energy scale calibration and from jet transverse momentum resolutions. All other uncertainty sources are negligible. The systematic uncertainties are 1–5% for $M_{jj} < 1\,\text{TeV}$ and 3–11% for $M_{jj} > 1\,\text{TeV}$; in all cases they are smaller than statistical uncertainties.

The results are compared to the predictions from a next-to-leading order calculation computed using fastNLO based on NLOJET++. The calculation uses MSTW2008NLO PDFs and the renormalization and factorization scales are set to the average transverse momentum of the two selected jets. The theory prediction, corrected for the nonperturbative effects estimated from PYTHIA is in a good agreement with the data. The pQCD prediction together with the selected predictions of new physics models are shown in Fig. 2.

For the new physics models limit settings, a χ^2 between the data and theory is formed and then transformed into a likelihood which is used in a Bayesian procedure to obtain 95% C.L. limits on new physics scales. The obtained limits provide one of the most stringent limits for quark compositeness and ADD models; in the case of TeV^{-1} extra dimensions, the limits are complementary to stronger limits obtained from indirect electroweak precision measurements.

5. Dijet Invariant Mass

The dijet invariant mass measurement [4] can be used to test the predictions of pQCD, to constrain PDFs and to search for signals of new physics. The dijet invariant mass (M_{jj}) is computed from the four momenta of the two jets with the highest transverse momenta in the event. Both jets are required to have $p_T > 40\,\text{GeV}$ and to have rapidities $|y| < 2.4$. There are 6 bins of jet rapidities, binned according to the higher rapidity of the two selected jets ($|y|_{\max}$). Bin sizes in M_{jj} are chosen to be about twice the dijet mass resolution and to have an efficiency and purity of about 50% as determined using a parameterized detector simulation. The efficiency is defined as the ratio of number of Monte Carlo events generated and reconstructed to those generated in a M_{jj} bin, and the purity is defined as the ratio of Monte Carlo events generated and reconstructed in a M_{jj} bin to all events reconstructed in that bin.

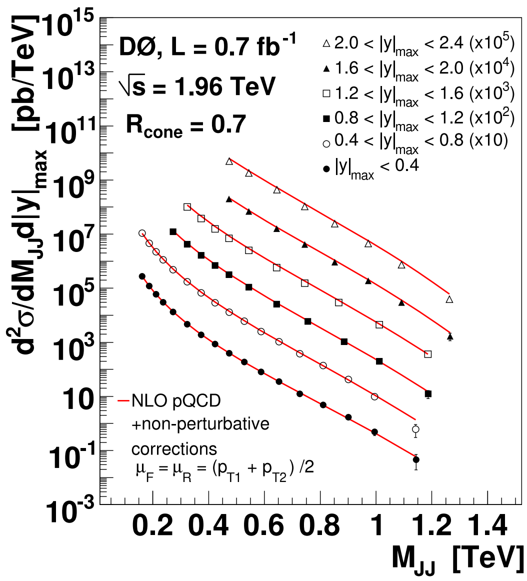

Figure 3: Dijet invariant mass cross section is six bins of the maximum jet rapidity.

The total experimental corrections to the data determined using the simulation are less than $\pm 2\%$ across the whole dijet invariant mass range for $|y|_{\max} < 0.8$, vary from 0.5% at $M_{jj} = 0.4\,\text{TeV}$ to 22% at 1.2 TeV for $0.8 < |y|_{\max} < 1.6$, and from 1% at $M_{jj} = 0.4\,\text{TeV}$ to 11% at 1.3 TeV for $1.6 < |y|_{\max} < 2.4$.

The total systematic uncertainty is dominated by the uncertainty coming from the jet energy scale calibration and ranges from 6% to 22% in the central up to 15% to 45% in the forward region of the calorimeter.

PoS(DIS 2010)113

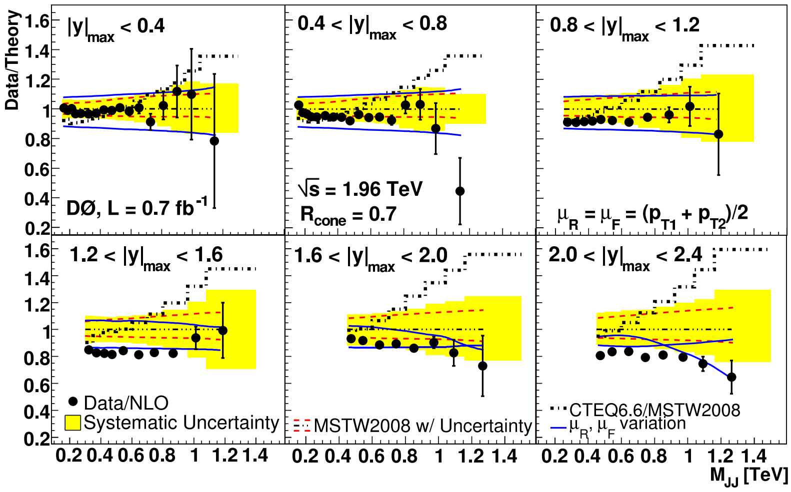

Figure 4: Data over theory comparison of the dijet mass cross section. The systematic uncertainty (yellow band) does not include additional 6% uncertainty due to luminosity. The scale dependence (solid blue line) is estimated by varying the scale up and down by a factor of 2. The uncertainty due to the PDF is shown red dashed line. For comparison the cross section difference between the CTEQ6.6 and MSTW2008 PDF is shown by black dash-dotted line.

The data are compared to the next-to-leading order prediction calculated using fastNLO program based on NLOJET++. The calculation uses MSTW2008NLO PDF sets and is corrected for underlying event and hadronization effects. The correction for this effects is obtained by turning on and off these effects individually in PYTHIA, the size of these effects range between -10% to 23% depending on the M_{jj}. The renormalization and factorization scales are chosen to be equal and set to the average transverse momentum of the two selected jets ($\mu = \mu_r = \mu_f = (p_{T1} + p_{T2})/2$) and the scale dependence is estimated by varying the scales simultaneously up and down by a factor of 2. The measured cross sections are presented in Fig. 3, while the detailed comparison of ratio of the data over the theoretical expectation is shown in Fig. 4.

6. Summary and Conclusions

Several interesting dijet variables were measured by the DO collaboration in the Run II of the Tevatron Collider. The measurements are well described by the NLO predictions of QCD and the χ_{dijet} sets the best limits in some models beyond the Standard model.

The author is supported by the grant MSM6840770039 of the Czech Ministry of Education.

References

[1] V. M. Abazov *et al.*, (D0 Collaboration), Nucl. Instrum. Methods Phys. Res. A **565**, 463 (2006).

[2] V. M. Abazov *et al.*, (D0 Collaboration), Phys. Rev. Lett. 94, 221801 (2005) and references therein.

[3] V. M.Abazov *et al.*, (D0 Collaboration), Phys. Rev. Lett. 103, 191803 (2009) and references therein.

[4] V. M. Abazov *et al.*, (D0 Collaboration), submitted to Phys. Lett. B, arXiv.org:1002.4594 and references therein.

PoS(DIS 2010)113