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Jet Correlation Studies as a Function of Rapidity Interval at D0

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Jet Correlation Studies as a Function of Rapidity Interval at DØ[1]

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Abstract

During the 1992–93 collider run of the Fermilab Tevatron the DØ experiment accumulated a large sample of events with jets in the final state. Since the DØ detector can trigger on jets over the entire pseudorapidity range $|\eta| < 3.2$, we collected a sample of events containing jets separated by large rapidity intervals. Such events may not be well described by LO or NLO QCD perturbative calculations due to the increased importance of additional gluon radiation which tends to decorrelate the leading jets in the event. These contributions can be included using a leading-log approximation (LLA) where the leading logarithmic terms are resummed to all orders in α_s as in HERWIG or the BFKL resummation calculation of Del Duca and Schmidt. We present the first experimental measurement of jet-jet ϕ correlations as a function of the rapidity interval of the η ordered jets. We compare these results to JETRAD, HERWIG and BFKL resummation predictions.

[1]Talk given at XXXth Rencontres de Moriond, " QCD and High Energy Interactions", March 19-26, 1995, Les Arcs, France

1 Introduction

To date Quantum Chromodynamics has enjoyed considerable success in describing jet production at colliders. Typically QCD calculations involve a perturbative expansion of the cross section in powers of the strong coupling constant, α_s, to leading order (LO) and next–to–leading order (NLO). [1],[2] To explore the strong force beyond this level, new studies are underway to probe higher order effects. These effects may manifest themselves as radiation between two jets separated in rapidity. The DØ detector is uniquely suited to carry out such a study with its ability to trigger on and reconstruct jets at large rapidity. We exploit these properties to study jet–jet correlations as a function of their rapidity separation.

By exploiting the factorization theorem, we can separate the cross section into two parts: one depending on the distribution of the incoming partons and the other involving solely the hard scattering matrix element. The matrix element, typically involving a large momentum transfer and a correspondingly small value of α_s, is calculable in the perturbative framework. This procedure will result in a reliable prediction provided that the terms neglected in the expansion are small. In certain situations where this criterion is not met, it may then prove necessary to rearrange the expansion to ensure that the large terms not previously taken into account are now included. This resummation can take many forms each summing different higher order contributions. Comparisons to experimental results are necessary to determine which method is valid.

In the case of jets separated by large rapidity intervals, large logarithms involving the ratio of the partonic center of mass energy, $\hat{s}$, and the square of the scale of the process, Q^2, enter the expansion. These logarithms can be rewritten as the rapidity separation between the jets ($\ln[\hat{s}/Q^2] \sim y$). As the rapidity interval increases, their effect on the higher order terms invalidates the perturbative expansion requiring a resummation. Del Duca and Schmidt have used the theory of Balitsky, Fadin, Kuraev, and Lipatov (BFKL) to resum the leading powers of the rapidity interval to all orders in α_s.[3] Alternatively, if these logarithms do not dominate at higher orders, more conventional resummations based on Altarelli–Parisi (GLAP) evolution equations that resum the collinear divergences may be sufficient to describe the data.

Measuring these effects directly poses daunting experimental challenges as they involve measuring relatively soft objects. To avoid these difficulties we prefer to infer the effects of the soft objects by studying the characteristics of the harder objects. In this case we study the correlation in ϕ of jets as a function of their separation in rapidity. We begin by measuring the qualitative correlations by plotting $\Delta\phi = \phi_1 - \phi_2$ of the two jets with the largest rapidity separation in each event. We then proceed to a more quantitative measurement by plotting $< \cos(\pi - \Delta\phi) >$ vs. $\Delta\eta$ ($\Delta\eta = \eta_1 - \eta_2$). Total correlation independent of $\Delta\eta$ will manifest itself as a horizontal line at $< \cos(\pi - \Delta\phi) > = 1$. Any deviation from unity corresponds to decorrelation. To evaluate the various QCD predictions, we compare our experimental measurements of the two jet ϕ correlation at large rapidity separation to a NLO prediction (JETRAD[4]), a parton shower Monte Carlo including collinear resummation (HERWIG[5]), and predictions based on BFKL resummation preformed by Del Duca and Schmidt.

2 Event Selection

As the DØ detector is described in detail elsewhere[6], only the portions relevant to this analysis will be described here. DØ has a uranium–liquid argon sampling calorimeter covering the pseudorapidity region $|\eta| < 4.2$ and 2π in azimuth. It has fine longitudinal and transverse segmentation providing good jet energy and position resolution.

The data for this study were taken with a trigger consisting of three levels. The first level (L0) required hits in beam–beam scintillation counters signalling the presence of an inelastic collision. The second level (L1) required localized energy deposits in $0.2 \times 0.2 (\Delta\eta \times \Delta\phi)$ towers in the calorimeter. The third level (L2) required a jet with $|\eta| < 3.2$. L2 utilized a cone based jet–finding algorithm with a radius ($\mathcal{R} = \sqrt{\Delta\eta^2 + \Delta\phi^2}$) of 0.7 using calorimeter cell information. For this analysis, one tower above 7 GeV at L1 and one jet

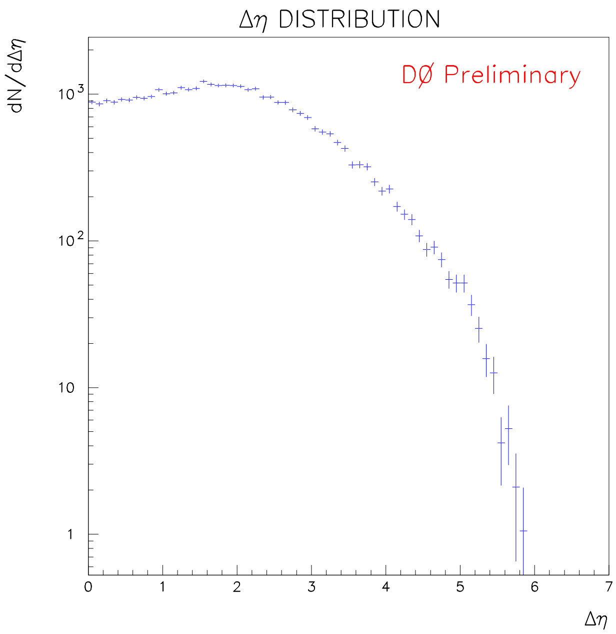

Figure 1: $\Delta\eta$ distribution for events used in this analysis.

above 30 GeV at L2 were required. For the run, 137 nb^{-1} were written to tape.

Jet energy scale corrections were applied offline and spurious jets removed before a minimum E_T cut of 20 GeV and a rapidity cut of $|\eta| < 3.0$ were applied to ensure jet reconstruction efficiency over the entire region of acceptance. Of the remaining jets, we are interested in the two with the largest rapidity separation in each event, e.g. the one most forward and the one most backward which we arbitrarily label jet 1 and jet 2. At this point we do not consider the other jets in the event. To remove any possibility of trigger bias one of these two jets was required to have $E_T > 50$ GeV.

3 Results

The DØ calorimeter is a unique device in its ability to trigger on and reconstruct jets for all $|\eta| < 3.2$. The results of these capabilities can be seen in Fig. 1 where the range of $\Delta\eta$ is displayed. This distribution includes rapidity separations as great as 6.

In Fig. 2 we plot the normalized distribution of the difference in azimuthal angle between the two jets with the largest rapidity separation in each event

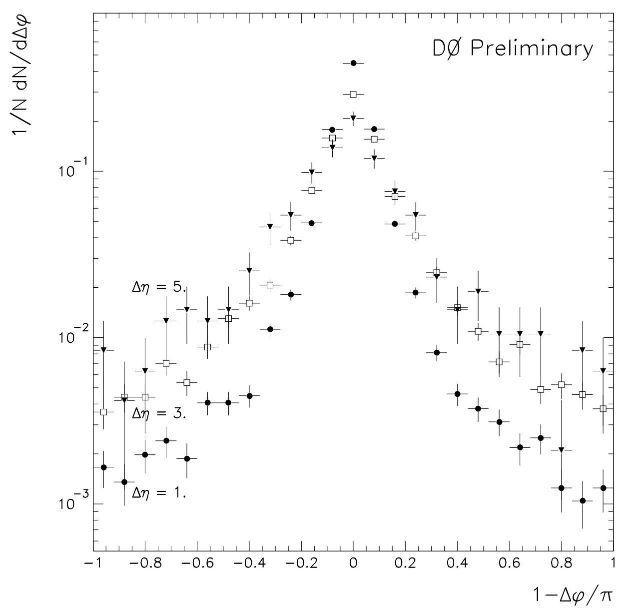

Figure 2: $\Delta\phi$ distribution for $\Delta\eta = 1$, 3, and 5. The decorrelation is evident in the height of the normalized peak as well as the side bands.

$(1/NdN/d\Delta\phi)$ for three different $\Delta\eta$: $\Delta\eta = 1$, 3, and 5. Since these distributions are normalized, decorrelation can be seen in the relative height of the central peaks as well as the side bands. The peak at zero ($1 - \Delta\phi/\pi = 0$) corresponds to a highly correlated dijet system. From the plot we see that as the rapidity separation between the jets increases the jets become less and less correlated. This gives a qualitative idea about the decorrelation, but a more quantitative correlation variable is necessary.

To this end, we have chosen to use $< \cos(\pi - \Delta\phi) >$ to quantify the correlation of the two jets. In Fig. 3 we plot $< \cos(\pi - \Delta\phi) >$ vs. $\Delta\eta$ for our data, JETRAD, HERWIG, and the BFKL resummation calculations of Del Duca and Schmidt. From the plot we see that the data show a linear decorrelation effect from $\Delta\eta = 0$ to $\Delta\eta = 5$. Although JETRAD appears to show qualitatively the correct correlation at small rapidity separation, it fails to model the decorrelation at large separations. HERWIG, shown here at the particle level, appears to model the decorrelation effects correctly over the entire range investigated. Initial studies indicate that hadronization effects are small. The BFKL resummation (valid only for $\Delta\eta > 2.0$) seems to predict an excessive amount of decorrelation over this range. In this kinematic regime, the collinear radiation resummed by HERWIG is more important than the strongly rapidity ordered radiation in a BFKL resummation.

4 Conclusions

We have made the first measurement of jet–jet angular correlation as a function of rapidity separation. We find that as the jet–jet rapidity interval increases the jets become less correlated. This decorrelation appears to be linear in the rapidity separation. We have compared our experimental measurement with various QCD predictions. We find that NLO QCD as modeled in the JETRAD Monte Carlo does not describe the data well, producing too little decorrelation at large rapidity separations. Resummation predictions in the form of HERWIG and a BFKL calculation performed by Del Duca and Schmidt were also examined. We find that HERWIG reproduces the experimental results over the whole rapidity range while the BFKL prediction tends to produce too much decorrelation in its range of validity.

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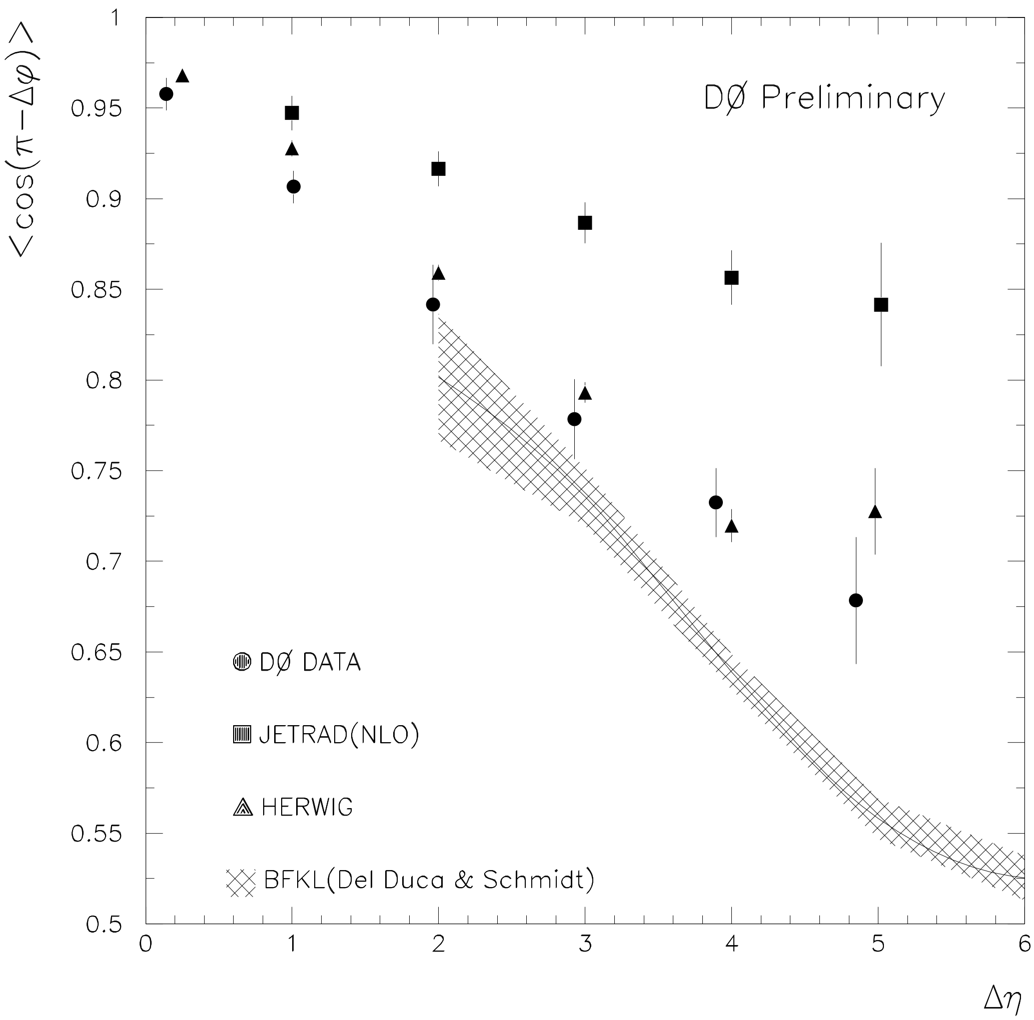

Figure 3: $< \cos(\pi - \Delta\phi) >$ vs. $\Delta\eta$ for our data and predictions from JETRAD, HERWIG, and the BFKL resummation calculations of Del Duca and Schmidt.

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