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The Dijet Mass and Angular Distributions at CDF

The CDF Collaboration

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ABSTRACT

The dijet mass and the dijet angular distribution, as measured in the CDF detector at the Fermilab Tevatron Collider, are compared to leading order (LO) and next-to-leading (NLO) order QCD calculations.

1. Jets: Experimental and Theoretical Definitions

Jets are observed in the CDF calorimeter[1] and are identified by the CDF clustering algorithm.[2] The main feature of this algorithm is that it defines a cone in $\eta - \phi$ space with radius R. The energy and momenta of all calorimeter towers within the cone are summed to give a single four-vector for each jet. A similar algorithm is used for the next-to-leading order calculations[3] where only three partons exist in the final state. If two of the partons fall within a cone, they are summed into one "jet".

The data are corrected for detector effects such as nonlinear calorimeter response to low energy particles and for energy lost in cracks between detectors. Recent theoretical calculations include the effect of energy lost outside the jet cone, although there is still a large uncertainty associated with underlying event energy. In order to present the data in a manner which is independent of the assumptions about the underlying event and out-of-cone energy, we do not attempt to correct the data for these effects.

2. Dijet Variables

The cross section for dijet events can be written[4] in terms of the mass, M_{JJ}, the center-of-mass scattering angle, θ^*, and longitudinal boost of the dijet system, $\eta_{boost} = (\eta_1 + \eta_2)/2$, where η_1 and η_2 are the pseudorapidities of the two highest E_T jets. The dijet mass of an event is defined in terms of the four-vectors of the leading two jets. The scattering angle is related to η_1 and η_2 by the equations $\eta^* = (\eta_1 - \eta_2)/2$ and $\cos\theta^* = \tanh\eta^*$. For comparisons to theory, the angular distribution is plotted in terms of the variable $\chi = e^{2|\eta^*|}$. For t-channel exchange, which dominates at large η^* , the $dN/d\chi$ spectrum is expected to be flat and thus insensitive to smearing effects.

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To obtain the best mass resolution for the dijet mass spectrum, the rapidities of the leading two jets are restricted to the region $|\eta| < 0.7$. For the angular distribution, where the extension to high values of η^* (χ) is more important than mass resolution, cuts requiring $|\eta_{boost}| < 0.75$ and $|\eta^*| < 1.6$ are imposed. These cuts more than double the angular range of the previous CDF measurement.[4] To ensure a fully efficient trigger over this larger angular range, the data is divided into mass windows of $240 < M_{JJ} < 475$ GeV, $475 < M_{JJ} < 550$ GeV and 550 GeV $< M_{JJ}$.

3. Comparisons to Theoretical Predictions

Fits of the dijet mass spectrum to LO QCD have been discussed in Ref. 1 for a variety of renormalization scales and structure functions (DFLM, DO, EHLQ, HMRS, and the four Morfin-Tung sets). To summarize, for a cone size of 1.0 all structure functions fit the data well (40-60% confidence level) except EHLQ2 (21-25%), and the results are almost independent of the choice of scale. With a cone size of 0.7, all of the fits give confidence levels less than 6%. Figure 1a shows an example of LO QCD compared to the CDF data. NLO calculations for a cone size of 0.7 have recently become available[5] and an early study indicates some improvement in the agreement between data and theory.

In the comparison of the dijet angular distribution to the theoretical calculations, fits are performed in which the normalization is a free parameter. With this approach we are sensitive to the shape of the $dN/d\chi$ distribution. Acceptance corrections are derived by comparing the shape of the angular distribution before and after a detector simulation. By varying the relative energy scales in different detector regions, upper and lower bounds representing the uncertainty in the acceptance corrections are derived. The data is corrected with the nominal, upper, and lower acceptance corrections and then fit to the theory. The range in the confidence levels represents the systematic uncertainty in the measurement.

Figure 1b shows the acceptance corrected data compared to LO and NLO calculations[5] for HMRSB sturcture functions and with LO QCD for the Morfin-Tung sets. The theoretical curves are plotted with the best-fit normalization. Table 1 summarizes the results of the fits for the LO and NLO predictions. Four sets of Morfin-Tung structure functions were tested (S, B1, B2 and E); they gave the same confidence levels to within 2%.

4. Conclusions

The dijet mass spectrum has been measured in the CDF detector for cone sizes of R = 0.7 and 1.0. The LO theory shows much better agreement with the R = 1.0 measurement than for R = 0.7. The NLO prediction has recently become available for R = 0.7 and there are indications of improved agreement with the data.

The dijet angular distribution has been measured for a cone size of R = 0.7 over a large angular region. Comparisons to theoretical predictions show that the NLO

Table 1: LO and NLO theory compared to the CDF dijet angular distribution. The range in confidence levels (C.L.) represents the systematic uncertainty. Preliminary.

Structure function	Mass (GeV)	LO C.L. (%)	NLO C.L. (%)
Morfin-Tung	240-475	37-60	-
HMRSB	240-475	31-53	41-60
Morfin-Tung	475-550	33-78	-
HMRSB	475-550	11-48	73-78
Morfin-Tung	>550	0.4-15	-
HMRSB	>550	≤10	6-15

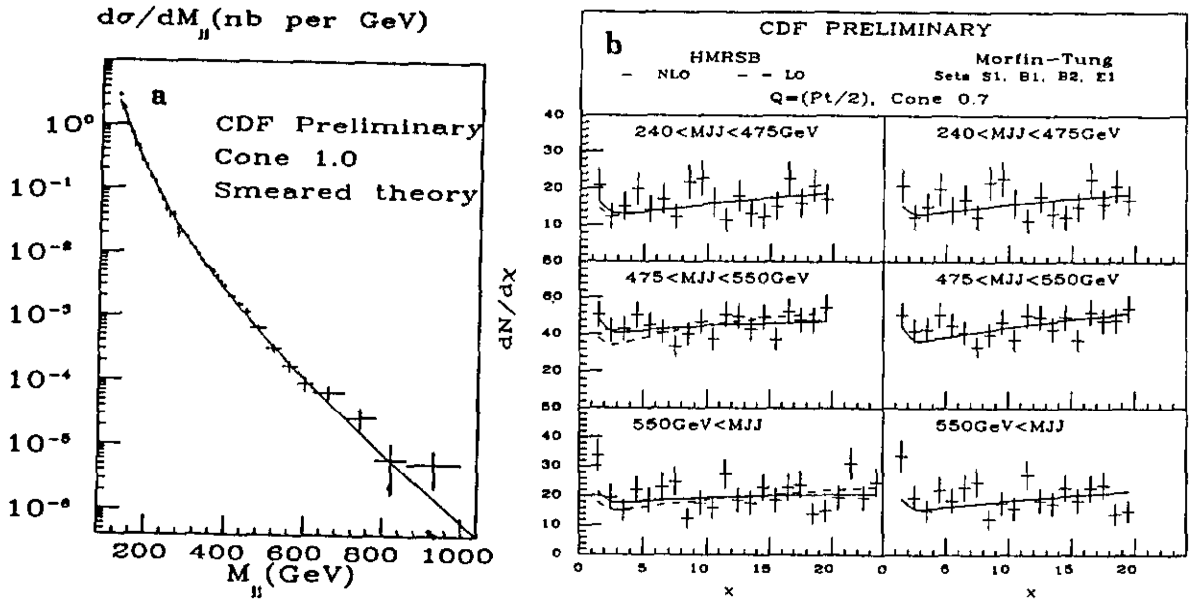

Figure 1: CDF dijet mass (a) and angular distribution (b) compared to QCD.

calculations fit the data somewhat better than LO when HMRSB structure functions are used. However, LO calculations with Morfin-Tung structure functions fit the data as well as the NLO calculations with HMRSB.

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