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Measurement of Dijet Azimuthal Decorrelations in $p\bar{p}$ Collisions

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Correlations in the azimuthal angle between the two largest transverse momentum jets have been measured using the DØ detector in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The analysis is based on an inclusive dijet event sample in the central rapidity region corresponding to an integrated luminosity of $150\,\mathrm{pb}^{-1}$. Azimuthal correlations are stronger at larger transverse momenta. These are well-described in NLO pQCD, except at large azimuthal differences where soft effects are significant.

Keywords: D0; QCD; jets.

A clean and simple way to study QCD radiative processes is to examine their impact on angular distributions. Dijet production, in the absence of radiative effects, results in two jets with equal p_T and correlated azimuthal angles $\Delta\phi = |\phi_{jet\,1} - \phi_{jet\,2}| = \pi$. Additional soft radiation causes small azimuthal decorrelations, whereas $\Delta\phi \lll \pi$ is evidence of additional hard radiation. Exclusive three-jet production populates $2\pi/3 < \Delta\phi < \pi$ while smaller values of $\Delta\phi$ require additional radiation such as a fourth jet in an event. Distributions in $\Delta\phi$ provide an ideal testing ground for higher-order pQCD predictions without requiring the reconstruction of additional jets and offer a way to examine the transition between soft and hard QCD processes based on a single observable.

Data were obtained[1] with the DØ detector[2] in Run II of the Fermilab Tevatron Collider using $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The primary tool for jet detection was a compensating, finely segmented, liquid-argon and uranium calorimeter that provided nearly full solid-angle coverage. Jets are defined using an iterative seed-based cone algorithm (including mid-points) with radius 0.7.[3] The observable is defined as the differential dijet cross section in $\Delta\phi$, normalized by the dijet cross section integrated over $\Delta\phi$ in the same phase space $(1/\sigma_{dijet})\,(d\sigma_{dijet}/d\Delta\phi)$. Theoretical and experimental uncertainties are reduced in this construction. Four analysis regions were defined based on the jet with largest p_T in an event (p_T^{max}). The second leading p_T jet in each event was required to have $p_T > 40$ GeV and both jets were required to have $|y_{jet}| < 0.5$.

The data are presented in Fig. 1 as a function of $\Delta\phi$. The spectra are strongly peaked at $\Delta\phi \approx \pi$; the peaks are narrower at larger values of p_T^{max}. Overlaid on the data points in Fig. 1 (left) are the results of pQCD calculations obtained using the parton-level event generator NLOJET++.[4] The observable was calculated from the ratio of the predictions for $2 \to 3$ processes ($d\sigma_{dijet}/d\Delta\phi$) and $2 \to 2$ processes (σ_{dijet}), both at LO or NLO. NLO pQCD provides a good description of the data. Results from pQCD at large $\Delta\phi$ in Fig. 1 (left) were excluded because fixed-order perturbation theory fails to describe the data in the region $\Delta\phi_{dijet} \approx \pi$ where soft processes dominate.

ALPGEN[5] is a recent parton-level event generator increasingly often used in studies of top and Higgs production. Verification of its performance using high-statistics QCD processes is of clear interest for applications that require accurate description of processes with several jets. Multi-jet configurations are produced by incorporating high order tree-level pQCD diagrams with the phenomenological parton-shower model from PYTHIA.[6] Samples for $2 \to 2, 3, \ldots, 6$ jet production were combined using the MLM matching scheme to avoid double counting contributions between multiplicity bins (Fig. 2 left). The combined ALPGEN calculation agrees reasonably well with the data (Fig. 2 right). Further comparisons of ALPGEN predictions to data are currently underway at DØ.

Monte Carlo event generators, such as HERWIG[7] and PYTHIA, use $2 \to 2$ LO pQCD matrix elements with phenomenological parton-shower models to simulate higher order QCD effects. Results from HERWIG (v6.505) and PYTHIA (v6.225), using default parameters, are compared to the data in Fig. 1 (right). HERWIG describes the data well over the entire $\Delta\phi$ range including $\Delta\phi \approx \pi$. PYTHIA with default parameters describes the data poorly—the distribution is too narrowly peaked at $\Delta\phi \approx \pi$ and lies significantly below the data over most of the $\Delta\phi$ range. The maximum p_T in the initial-state parton shower is directly related to the maximum virtuality that can be adjusted in PYTHIA via the parameter `PARP(67)`. The shaded bands in Fig. 1 (right) indicate the range of variation when `PARP(67)` was increased from the current default of 1.0 to 4.0 which was default before v6.138. These variations result in significant changes in the low $\Delta\phi$ region clearly demonstrating the sensitivity of this measurement. Consequently, global efforts to tune Monte Carlo event generators should benefit from including our data.

References

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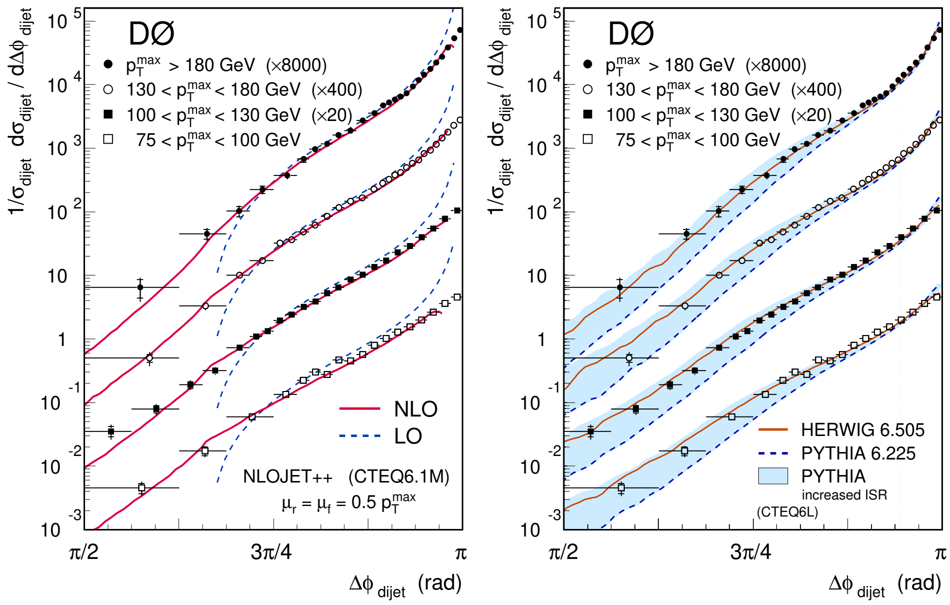

Fig. 1. The $\Delta\phi$ distributions in four regions of p_T^{max}. Left: Data overlayed with results from LO & NLO pQCD calculations. Right: Data overlayed with results from HERWIG and PYTHIA.

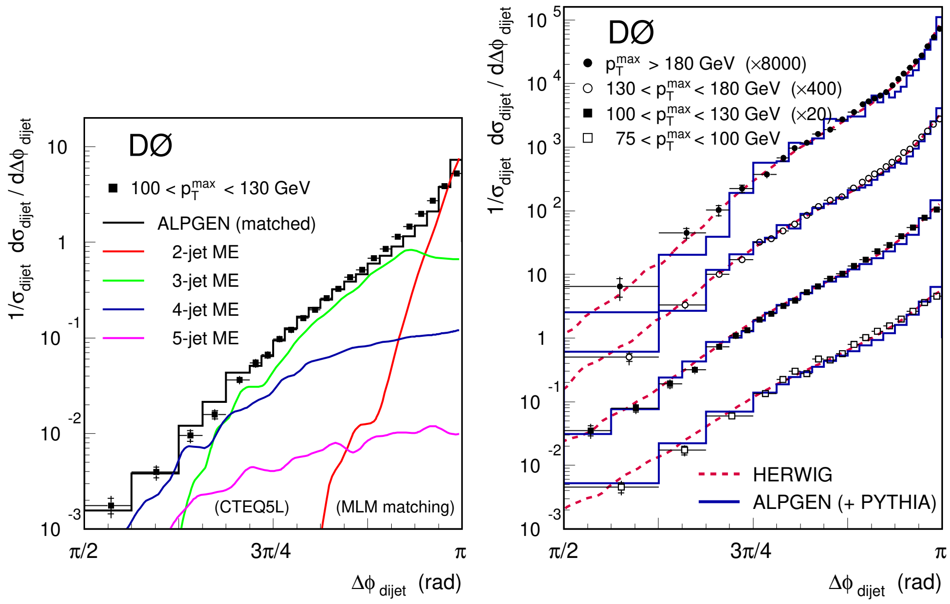

Fig. 2. Left: Contributions from different multiplicity bins in ALPGEN compared to the data in one p_T^{max} bin. Right: The $\Delta\phi$ distributions in four regions of p_T^{max} overlayed with results from ALPGEN & PYTHIA and HERWIG.