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Angular correlations between b jets in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV

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We present a preliminary measurement of angular correlations between b jets. The distribution of $\Delta\phi$ between a muon-tagged jet and a lifetime-tagged jet in data is compared to individual distributions for gluon splitting, flavor excitation and flavor creation $b\bar{b}$ processes, and background. The relative contributions of gluon splitting, flavor excitation and flavor creation to the data distribution are determined.

Keywords: Heavy flavor production, QCD

1. Introduction

In Next-to-Leading-Order (NLO) QCD $b\bar{b}$ production, a distinction can be made between *flavor creation* (FCR), *gluon splitting* (GSP) and *flavor excitation* (FEX) processes. The distinction between the processes is described in more detail in [1,2].

b Quarks produced through the FCR process emerge back-to-back in azimuth. The GSP process favors b quarks that are very close in phase space. In FEX processes, the b quarks are not strongly correlated in azimuth, but one b will be produced at high momentum relative to the incoming (anti-) proton beam while the other b quark will emerge very close to the beam direction.

The relative contribution from each process and the contribution from lighter flavors are determined using a maximum likelihood fit to the azimuthal correlation $\Delta\phi$ between two b jets in events with one jet tagged by a muon and one jet using a lifetime tag.

2. Data Sample and Event Selection

This measurement uses 7.8 ± 0.6 pb^{-1} of collision data taken in 2002 and selected with a trigger requiring the presence of muon scintillator hits and a 5 GeV calorimeter tower at Level 1, a muon track at Level 2 and a 20 GeV jet at Level 3.

Off-line, each event was required to have at least two reconstructed $R < 0.5$ cone jets with $|\eta| < 1$ and $E_T > 15$ GeV. One of the jets was required to have a matching muon within $\Delta R < 0.7$, reconstructed in the central muon system and with $p_T > 6$ GeV/c. A primary vertex with $|z| < 22$ cm was also required.

A second jet was required to be tagged with an impact parameter tag. Because of the long lifetime of B hadrons, the trajectories of their decay particles will be displaced from the beam. This displacement is referred to as the impact parameter (d_0). The *significance*, defined as $S = d_0/\sigma_{d_0}$, is used to compute the probability that a track comes from a background process. To determine the probability that a jet is consistent with a background process, the combined probability of all tracks within a $\Delta R < 0.5$ cone around the jet is computed. The signal and background efficiency of the impact parameter tag as a function of jet E_T, η and ϕ are determined from a sample of muon jets and from a background sample, respectively.

3. Definitions

The relative contributions of FCR, GSP, FEX and background processes to the data are determined by fitting the MC $\Delta\phi$ and P_T^{Rel} distributions (called *templates*) to the 2D data $\Delta\phi$-P_T^{Rel} distribution.

Muon jets arise from the semileptonic decays of b- and c-flavored hadrons and in-flight decays of light mesons. The transverse momentum of the muon with respect to the muon+jet axis (P_T^{Rel}) is on average higher for b decays and is used to distinguish them from other processes. The MC P_T^{Rel} templates were made by fully reconstructing MC events, taking into account the jet and muon resolutions and the trigger efficiency in data. The b jet P_T^{Rel} template includes muons from $\mathrm{b} \to \mathrm{c} \to \mu$ decays.

The $\Delta\phi$ templates were made by selecting MC events with two reconstructed jets, each matched to a B hadron within a $\Delta R < 0.5$ cone around the jet. Because of the limited size of the samples, a reconstructed muon and an impact parameter tag were not required. Instead, one of the jets was required to have $E_T > 21$ GeV to account for the additional energy carried by the muon. Each event was assigned a weight to account for the impact parameter tagging efficiency and for the probability to have a matched muon in the central region.

The Monte Carlo (MC) samples were generated with PYTHIA 6.158 [3], followed by a GEANT simulation of the DØ detector response and reconstruction. The CLEO QQ [4] package was used for B decays. Separate samples were generated for FCR, GSP, and FEX $\mathrm{b\bar{b}}$ production processes, and for $\mathrm{c\bar{c}}$ and light jet backgrounds.

4. Results

The data sample still contains background events due to fake tags. If the muon jet is not a b jet, the event will be correctly identified as a background event by the P_T^{Rel} component of the fit. If the muon jet is a b jet but the away jet is a falsely tagged light jet, the event is identified as signal by the fit even though it should be considered background. The fraction of these *fake IP tag* events is determined using a matrix method calculation. At different operating points (i) of the impact parameter tag, the number of $\mathrm{b} \to \mu$ decays is given by:

$$N^{(i)}_{\mathrm{b}\to\mu} = \epsilon^{(i)}_{\mathrm{background}} \times N_{\mathrm{fake}} + \epsilon^{(i)}_{\mathrm{b}} \times N_{\mathrm{signal}}, \tag{1}$$

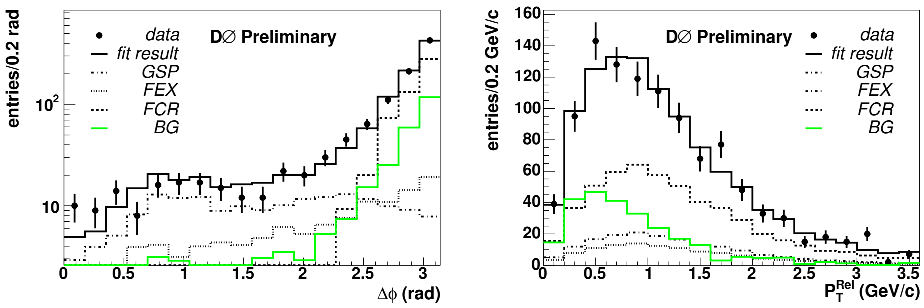

Fig. 1. Data $\Delta\phi$ and P_T^{Rel} distributions for jets with $E_T > 15$ GeV and $|\eta| < 1$. The weighted templates normalized to their total contribution to the fit result are also shown.

where $N^{(i)}_{\mathrm{b}\to\mu}$ is the number of muon b jets remaining at operating point (i), N_{fake} is the number of *fake IP tag* events and N_{signal} is the number of $\mathrm{b\bar{b}}$ events in the untagged sample. Using the known efficiencies for signal and background at two operating points (*loose*) and (*tight*), the fraction of *fake IP tag* events remaining in the sample after applying the impact parameter tag is determined to be $(3.0\pm0.8)\%$.

The P_T^{Rel} and $\Delta\phi$ projections of the data with the fit result are shown in Fig. 1. The relative contributions of FCR, GSP, FEX and background processes, after correcting for *fake IP tag* events, are given in Table 1. To compare the result to an inclusive $\mathrm{b\bar{b}}$ sample generated with PYTHIA 6.158 and corrected for the acceptance of the data, the background fraction was subtracted and the normalized FCR, GSP and FEX fractions are also given in the table. The systematic uncertainties are still under study. With the full DØ dataset and improved reconstruction software, statistical and systematic uncertainties will be reduced to very low levels.

Table 1. Relative contributions of FCR, GSP and FEX to the production of two central b jets. The background includes the *fake IP tag* background. In the last two columns, the FCR, GSP and FEX contributions have been normalized to sum to unity. Only statistical uncertainties are shown.

Process	Before removing background	After removing background	PYTHIA
Flavor creation	0.45 ± 0.04	0.63 ± 0.04	0.47 ± 0.05
Gluon splitting	0.17 ± 0.03	0.23 ± 0.04	0.43 ± 0.05
Flavor excitation	0.10 ± 0.04	0.14 ± 0.05	0.10 ± 0.03
Background	0.28 ± 0.04	0	0

References

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