Diffractive heavy flavor production at CDF

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We report results of diffractive production of heavy flavors, charm and beauty, from CDF.

We extended our studies of diffractive processes to diffractive heavy flavor production, charm and beauty, to probe directly the gluon content of the pomeron. Our diffractive beauty [1] production measurement is based on identifying a high transverse momentum electron with $E_T > 9.5$ GeV and $|\eta| < 1.1$, from the semi-leptonic b-quark decay, produced in single diffraction dissociation, $p + \bar{p} \to p/\bar{p} + b(\to e + X') + X$. Each event is required to have a jet consisting of at least two tracks in addition to the electron candidate.

First, we extract a diffractive signal from the obtained event sample and then estimate the b-quark fraction separately in the diffractive and total event samples.

As in our diffractive dijet[2] and W [3] analyses, the diffractive signal is extracted by counting BBC hits, N_{BBC}, and adjacent forward calorimeter towers, N_{CAL}, with $E > 1.5$ GeV. Figure 1(a) shows the correlation between N_{BBC} and N_{CAL} for both the positive and negative η sides of the detector, i.e. two entries per event. The (0,0) bin contains 100 events. We evaluate the non-diffractive content of the (0,0) bin from the distribution of events along the diagonal of Fig. 1(a), with $N_{BBC} = N_{CAL}$, shown in Fig. 1(b) by extrapolating a fit to the data of bins (2,2) to (9,9) to bin (0,0). This yields 24.4$\pm$5.5 non-diffractive background events in the (0,0) bin.

Figures 1(c) and 1(d) show the electron E_T and η distribution, respectively, for the diffractive (points) and total (histogram) event samples. In Fig. 1(d), the sign of η of diffractive events with a gap at positive η was changed, so that the gap always appears at negative η. While the E_T spectra show no significant difference, the diffractive η distribution is shifted away from the gap relative to the symmetric distribution of the total event sample, in agreement with the single diffraction event topology.

In addition to events from b-quark decays, the data contain events from charm decays and background. The background is mainly due to electrons from residual photon conversions and to hadrons faking electrons.

We use two methods to extract the fraction of beauty events in the data. In the first method, we fit the electron momentum component perpendicular to the jet axis, $p_T^{e/jet}$, which depends on the mass of the parent quark, with the sum of four templates: photon conversions, fake electrons from hadrons, charm and beauty. This fit yields a beauty fraction of (42.9$\pm$0.4)% [(38$\pm$14)%] for the total [diffractive] event sample. The second method uses the impact parameter of the electron track, which is defined as the minimum distance between the primary vertex and the electron track in the $r-\phi$ plane and depends on both the mass and the lifetime of the parent quark. A fit to the impact parameter distribution using four templates, as above, yields (47.7 ± 0.4)% [(38 ± 14)%] for our two data samples.

The average of the results of both methods yields $73371 \pm 485(stat) \pm 7774(syst)$ [$44.4 \pm 10.2(stat) \pm 4.7(syst)$] beauty events for the total [diffractive] event sample. The difference between the results of the two methods is assigned as systematic uncertainty. After subtracting the 24% non-diffractive background estimated from the fit in Fig. 1(b), there remain $33 \pm 10(stat) \pm 5(syst)$ diffractive beauty events. Correcting the diffractive event yield for single-vertex selection cut efficiency (0.26 ± 0.01), and for the detector live-time acceptance (0.77 ± 0.07) due to noise or beam associated background, we obtain $165 \pm 50(stat) \pm 29(syst)$ diffractive beauty events.

The diffractive to total b-quark production ratio obtained from the above numbers is $R_{bb}^{gap} = [0.23 \pm 0.07(stat) \pm 0.05(syst)]$%. The rapidity gap acceptance for events generated using POMPYT Monte Carlo with a flat pomeron structure, which is favored by HERA measurements [4,5], and a gluon to quark ratio of 0.7 ± 0.2, as reported in ref. 3, is found to be 0.37 ± 0.02. Dividing $R_{\bar{b}b}^{gap}$ by this value yields a diffractive to total production ratio of

$$R_{\bar{b}b} = [0.62 \pm 0.19(stat) \pm 0.14(syst)]\% \quad (\xi < 0.1).$$

POMPYT with the standard pomeron flux and a flat (hard) pomeron structure consisting of purely gluons or quarks yields $R_{\bar{b}b}$ of 10.4%(11.6%) and 0.92%(1.02%), respectively. The ratio D of the measured $R_{\bar{b}b}$ fraction to that predicted by POMPYT depends on the gluon fraction f_g of the pomeron. This dependence is shown in Fig. 2, where D is plotted as a function of f_g along with published results from ZEUS and CDF measurements [2,3]. For each measurement the two curves show the 1σ bounds. The black cross and shaded ellipse represent the best fit and 1σ contour of a least square two-parameter fit to the three CDF results. The fit yielded $D_{CDF} = 0.19 \pm 0.04$ and $f_g^{CDF} = 0.54^{+0.16}_{-0.14}$, in agreement with the results we obtained from the W and dijet rates, namely $D = 0.18 \pm 0.04$ and $f_g = 0.7 \pm 0.2$ [2]. The value of D_{CDF} is significantly smaller than the ZEUS result. The discrepancy between the HERA and Tevatron D-values represents a breakdown of factorization. The observed discrepancy is in general agreement with predictions based on the renormalized pomeron flux model [6].

We also searched for diffractive J/ψ production in a sample of central ($|\eta| < 1.1$) dimuons. For J/ψ reconstruction we required a pair of opposite charge muons with $p_T > 2$ GeV/c and invariant mass close to the J/ψ mass. The technique we used to extract the diffractive signal is identical to that used in our previous studies. Preliminary results of this analysis, before correcting for the gap acceptance A, give a ratio of diffractive to non-diffractive J/ψ production of

$$R_{J/\psi} \times A = [0.36 \pm 0.07]\%.$$

In spite of the fact that all diffractive processes studied at CDF are differently sensitive to the quark and gluon content of the pomeron, the obtained ratios of diffractive to non-diffractive production are all of the same order of magnitude, $\sim 1\%$. This indicates that the structure of the pomeron probed in single diffraction events is not very different from the structure of the proton.

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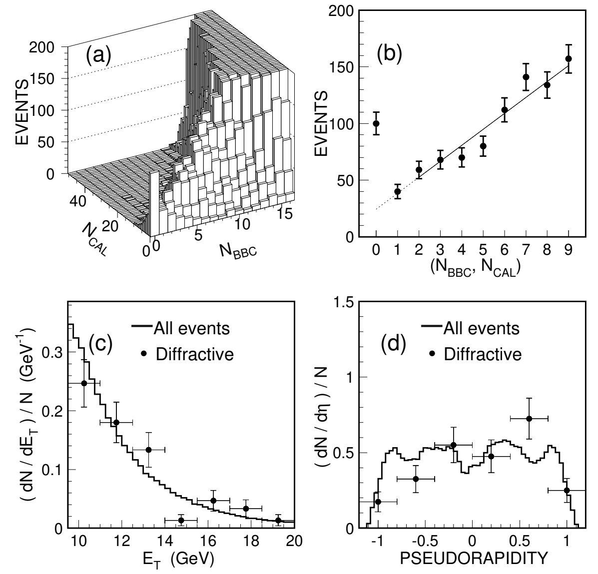

Figure 1. (a) Beam-beam counter multiplicity, N_{BBC}, versus forward calorimeter tower multiplicity, N_{CAL}; (b) multiplicity distribution along the diagonal with $N_{BBC} = N_{CAL}$ in the plot in (a); (c) electron p_T and (d) pseudorapidity for the diffractive (points) and total (histogram) event samples.

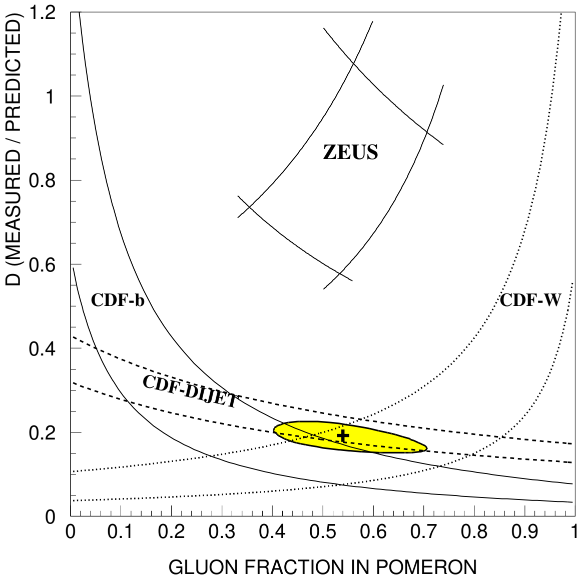

Figure 2. The ratio D of measured to predicted diffractive rates as a function of the gluon content of the pomeron.