Fermilab FERMILAB-Conf-00/281-E CDF December 2000

DIJET PRODUCTION BY DOUBLE POMERON EXCHANGE AT THE TEVATRON

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We report the observation of dijet events with a Double Pomeron Exchange topology produced in $\bar{p}p$ collisions at $\sqrt{s} = 1800\,\text{GeV}$. The events are characterized by a leading antiproton , two jets in the central pseudorapidity region, and a rapidity gap on the outgoing proton side. Results on kinematics, production rates, and comparisons with corresponding results from single diffractive and inclusive dijet production are presented.

Recently the CDF Collaboration reported a measurement of the structure function of the antiproton extracted from dijet events produced in single diffractive (SD) $\bar{p}p$ collisions at $\sqrt{s} = 1800$ GeV.[1] The results showed that the "diffractive structure function" measured by CDF is different, in both x-Bjorken dependence and normalization, from the corresponding proton structure function measured by the H1 Collaboration in diffractive deep inelastic scattering at HERA.[2] The Tevatron to HERA relative suppression of diffractive rates was found to be of $\mathcal{O}(0.1)$.[1,3] The SD dijet events, $\bar{p}+p \to \bar{p}' + jet1 + jet2 + X$, are characterized by a leading antiproton with fractional momentum loss ξ adjacent to a rapidity gap, defined as a region of pseudorapidity devoid of particles, which is due to the exchange of a color singlet state with vacuum quantum numbers, presumably a Pomeron. The difference between the diffractive structure functions at the Tevatron and at HERA implies that the Pomeron does not possess a process-independent structure function; in other words, the diffractive process does not obey QCD factorization.

In a sample of SD dijet events collected using a Roman Pot Spectrometer (RPS) triggering on a leading antiproton in diffractive $\bar{p}p$ scattering,[1] we selected events with Double Pomeron Exchange (DPE) topology by looking for a rapidity gap on the proton side. The x-Bjorken of the colliding partons in the protons and antiprotons are calculated using the expressions:

$$x_p = \frac{1}{\sqrt{s}} \sum_{i=1}^{N_{jet}} E_T^i e^{+\eta_i}, \quad x_{\bar{p}} = \frac{1}{\sqrt{s}} \sum_{i=1}^{N_{jet}} E_T^i e^{-\eta_i} \qquad (1)$$

where the sum is carried over the two highest transverse energy (E_T) jets plus a third jet if $E_T^{jet3} > 5$ GeV. In leading order QCD, the cross section ratio $R_{ND}^{SD}(x_{\bar{p}})$

of SD to non-diffractive (ND) dijet events as a function of $x_{\bar{p}}$ is equal to the ratio of the diffractive to ND structure functions of the $\bar{p}$. If QCD factorization holds, this ratio should be the same as the ratio $R_{SD}^{DPE}(x_p)$ of DPE to SD events, which in turn is equal to the ratio of the diffractive to ND structure function of the p. Comparing the two ratios R_{SD}^{DPE} and R_{ND}^{SD} at fixed x ($x_{\bar{p}}$, x_p) and ξ ($\xi_{\bar{p}}$, ξ_p), we can test factorization.

The SD dijet sample consists of events with dijets of $E_T^{jet} > 7$ GeV and a leading antiproton with fractional momentum loss $\xi_{\bar{p}}$ in the range $0.035 < \xi_{\bar{p}} < 0.095$ and 4-momentum transfer squared $|t_{\bar{p}}| < 1.0$ GeV^2.[1] The search for events with DPE topology was performed by looking for a rapidity gap on the outgoing p side. Fig. 1(a) shows the correlation between hit multiplicity N_{BBC_p} in the Beam-Beam Counters (BBC) covering the region $3.2 < \eta < 5.9$ and forward calorimeter tower multiplicity N_{FCAL_p} in the range $2.4 < \eta < 4.2$ on the p side. The clear excess of events with a rapidity gap in the (0,0) bin is attributed to DPE. The number of DPE events in the (0,0) bin was evaluated using the diagonal multiplicity distribution, shown in Fig. 1(b). Shown in Fig. 1(c) are the $\xi_{\bar{p}}$ distributions measured by the RPS in DPE (points) and SD (histogram) events. The rising trend of DPE relative to SD events with increasing $\xi_{\bar{p}}$ could be explained by a lower center of mass energy in DPE relative to SD. Replacing x by ξ in Eq. (1) and summing over all particles in the event yield the ξ_p and $\xi_{\bar{p}}$ in DPE events. Fig. 1(d) shows the obtained ξ_p distribution for the DPE events. To account for detector inefficiencies, we multiply the result by a factor 1.7, which was obtained by comparing the $\xi_{\bar{p}}$ measured by the RPS with $\xi_{\bar{p}}$ reconstructed from all particles.

Factorization demands that the two ratios R_{SD}^{DPE} and R_{ND}^{SD} should be the same at fixed x and fixed ξ. To test this property, we compare, in Fig. 2, the ratios $R_{SD}^{DPE}(x_p)$ and $R_{ND}^{SD}(x_{\bar{p}})$ in the kinematic range $7 < E_T^{jet1,2} < 10$ GeV, $0.035 < \xi_{\bar{p}} < 0.095$, $|t_{\bar{p}}| < 1.0$ GeV^2 and $0.01 < \xi_p < 0.03$ for DPE. Both ratios are normalized per unit ξ. The errors are statistical only; the systematic uncertainties are about $\pm 20\%$, which are common to both ratios, and they are not shown. The weighted average of the R_{SD}^{DPE} points within the vertical dashed lines corresponding to the kinematically full acceptance region is $\tilde{R}_{SD}^{DPE} = 0.80 \pm 0.26$. A ξ dependence of the ratio R is examined in the inset by looking at the weighted average $\tilde{R}(x)$ (per unit ξ) of R within the vertical dashed lines as a function of ξ. The ratio $\tilde{R}_{ND}^{SD}$, shown in six ξ bins in the region $0.035 < \xi < 0.095$, is flat in ξ. A straight line fit to six $\tilde{R}_{ND}^{SD}$ ratios extrapolated to $\xi = 0.02$ yields $\tilde{R}_{ND}^{SD} = 0.15 \pm 0.02$. The resulting ratio D of $\tilde{R}_{ND}^{SD}$ to $\tilde{R}_{SD}^{DPE}$ is $D \equiv \tilde{R}_{ND}^{SD}/\tilde{R}_{SD}^{DPE} = 0.19 \pm 0.07$. The deviation of D from unity represents a breakdown of factorization. Due to the presence of a rapidity gap on the $\bar{p}$ side in DPE and SD events, comparing DPE with a rapidity gap on the p side with SD at $\sqrt{s} = 1800$ GeV is similar to comparing SD with ND events at the reduced c.m. energy $\sqrt{\xi_{\bar{p}} s} \sim 450$ GeV. Our measured rate of DPE relative to SD events is about a factor 5 higher than the rate of SD relative to ND events. This situation

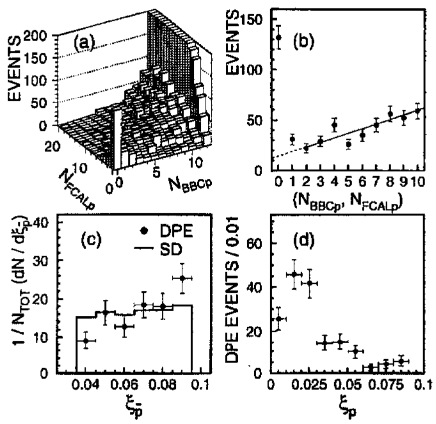

Fig. 1. (a) BBC hit multiplicity versus forward calorimeter tower multiplicity on the p side, (b) multiplicity distribution along the diagonal bins in (a), (c) $\xi_{\bar{p}}$ measured by RPS for the DPE (points) and SD (histogram) events, (d) ξ_p of the DPE events.

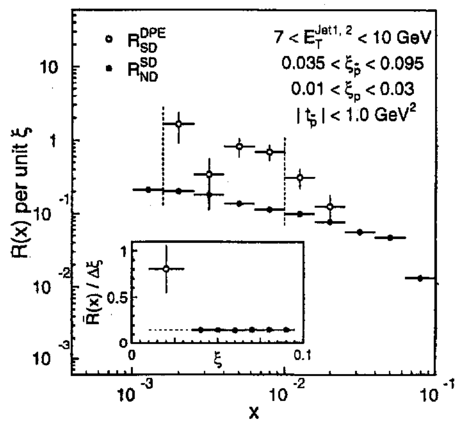

Fig. 2. Ratios of DPE to SD (SD to ND) dijet event rates per unit ξ_p ($\xi_{\bar{p}}$), shown as open (filled) circles, as a function of x_p ($x_{\bar{p}}$). The insert shows the weighted average of ratios within the vertical dashed lines per unit ξ versus ξ.

is analogous to the $\mathcal{O}(0.1)$ suppression of hard diffraction rates observed at the Tevatron[1,3] in $\sqrt{s} = 1800$ GeV relative to expectations based on the lower energy ($\sqrt{s} \approx 300$ GeV) diffractive deep inelastic scattering measurements at HERA.

The absolute DPE dijet production cross section is obtained by multiplying the DPE to SD ratio by the SD dijet cross section, which is normalized by scaling to the measured[4] inclusive (soft) diffraction cross section of 0.78 ± 0.16 mb. For the kinematic range $0.035 < \xi_{\bar{p}} < 0.095$, $0.01 < \xi_p < 0.03$, $|t_{\bar{p}}| < 1.0$ GeV^2 and dijets with $E_T > 7$ [$E_T > 10$] GeV confined within $-4.2 < \eta < 2.4$, we obtain $\sigma^{\rm DPE} = 43.6 \pm 4.4(stat) \pm 21.6(syst)$ [$3.4 \pm 1.0(stat) \pm 2.0(syst)$] nb, where the systematic errors are dominated by the uncertainties in normalization and jet energy calibration.

References

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