Hard diffraction at CDF

Konstantin Goulianos

The Rockefeller University, 1230 York Avenue, New York, NY 10065, USA
(On behalf of the CDF Collaboration)

We present a CDF measurement of diffractive dijet production in $\bar{p}p$ collisions at 1.96 TeV at the Fermilab Tevatron Collider using data from an integrated luminosity of $\approx 310 \text{ pb}^{-1}$ collected by triggering on a high transverse momentum jet in coincidence with a recoil antiproton detected in a roman pot spectrometer. We report final results for 4-momentum transfer squared $t > -4 \text{ GeV}^2$, antiproton-momentum-loss fraction within 0.03-0.09, Bjorken-$x$ of the interacting parton in the antiproton in the range 0.001-0.1, and jet transverse energies from 10 to 100 GeV.

1 Introduction

We present final results from a CDF measurement of single-diffractive (SD) dijet production in $\bar{p}p$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$ at the Fermilab Tevatron Collider using data collected by triggering on a high transverse momentum jet in coincidence with a recoil antiproton detected in a Roman Pot Spectrometer (RPS) [1]. We consider proton diffractive dissociation, $\bar{p} + p \rightarrow \bar{p} + G\bar{p} + Xp$, characterized by a rapidity gap (region of pseudorapidity devoid of particles) adjacent to an escaping $\bar{p}$, and a final state $X_p$ representing particles from the dissociation of the proton [2]. The rapidity gap, presumed to be caused by a color-singlet exchange with vacuum quantum numbers between the $\bar{p}$ and the dissociated proton, traditionally referred to as Pomeron ($P$) exchange, is related to $\xi_{\bar{p}}$, the forward momentum loss of the surviving $\bar{p}$, by $G_{\bar{p}} = -\ln \xi_{\bar{p}}$.

Several diffractive dijet results were obtained by CDF in Run I [3, 6]. Among these, most striking is the observation of a breakdown of QCD factorization, expressed as a suppression by a factor of $O(10)$ of the diffractive structure function (DSF) measured in dijet production relative to that derived from fits to parton densities measured in diffractive deep inelastic scattering (DDIS) at the DESY $e$-$p$ collider HERA (see [5]).

The present Run II diffractive dijet measurement was performed in order to further characterize the diffractive structure function by measuring $t_{\bar{p}}$ distributions over a wide range of $t$ and jet transverse energy, $E_{T}^{\text{jet}}$, namely $-t_{\bar{p}} \leq 4 \text{ GeV}^2$ and $10^2 < Q^2 \approx (E_{T}^{\text{jet}})^2 < 10^4 \text{ GeV}^2$, and to search for diffractive dips. Below, we present the main results of this measurement and compare them with theoretical expectations.

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1Rapidity, $y = \frac{1}{2} \ln \frac{E + p_T}{E - p_T}$, and pseudorapidity, $\eta = -\ln \tan \frac{\theta}{2}$, where $\theta$ is the polar angle of a particle with respect to the proton beam (+$\hat{z}$ direction), are used interchangeably for particles detected in the calorimeters, since in the kinematic range of interest in this analysis they are approximately equal.
2 Measurement

These measurements were performed using the Run II CDF detector and special data samples.

Detector  Figure 1 is a schematic plan view of the detector, showing the main CDF II central detector and the forward detector-components essential to this measurement. The forward components include a Roman Pot Spectrometer (RPS), which measures $\xi$ and $t_\bar{p}$ with resolutions $\delta \xi_\bar{p} = 0.001$ and $\delta t_\bar{p} = \pm 0.07 \text{ GeV}^2$ at $-t_\bar{p} \approx 0.05 \text{ GeV}^2$, where $\delta t_\bar{p}$ increases with $t_\bar{p}$ with a $\propto \sqrt{-t_\bar{p}}$ dependence.

Data samples  This analysis is based on data corresponding to an integrated luminosity of $\mathcal{L} \approx 310 \text{ pb}^{-1}$ collected in 2002–2003. Events were selected online with a three-level prescaled triggering system accepting RPS-triggered inclusive and jet-enriched events by requiring at least one calorimeter tower with $E_T > 5, 20, \text{ or } 50 \text{ GeV within } |\eta| < 3.5$. Jets were reconstructed using the midpoint algorithm \cite{7}.

The majority of the data used in this analysis were recorded without RPS tracking information. For these data, the value of $\xi_\bar{p}$ was evaluated from calorimeter information and is designated as $\xi_\bar{p}^{\text{CAL}}$. The $\xi_\bar{p}^{\text{CAL}}$ was then calibrated against $\xi$ obtained from the RPS, $\xi_\bar{p}^{\text{RPS}}$, using data from runs in which RPS tracking was available.

The following trigger definitions are used for these measurements:
• RPS: RPS trigger counters in time with a $\bar{p}$ crossing the nominal interaction point;
• J5 (J20, J50): jet with $E_T^{\text{jet}} \geq 5 (20, 50) \text{ GeV in CCAL or PCAL}$;
• RPS-Jet5 (Jet20, Jet50): RPS trigger in coincidence with J5 (J20, J50).

3 Results

In Fig. 2 we compare (left) the mean dijet transverse energy between SD and ND events, and on (right) the $x_{Bj}$ (Bjorken-$x$) distribution of the ratio of (SD/ND) event-rates for various values of $\langle Q^2 \rangle \approx \langle E^*_{T\bar{p}} \rangle^2$ over a range of two orders of magnitude. These plots show that the SD and ND distributions are very similar.

The $t$ distributions for RPS inclusive and various dijet event samples are shown in Fig. 3 (left) for $-t < 1 \text{ GeV}^2$ fitted to two exponential terms, and in Fig. 3 (right) for $-t < 4 \text{ GeV}^2$. No significant variations are observed over a wide rage of $\langle Q^2 \rangle$. For $-t < 0.5 \text{ GeV}^2$ all $t$ distributions, both for the inclusive and the high $\langle Q^2 \rangle$ samples, are compatible with the expectation from the “soft” Donnachie-Landshoff (DL) model \cite{5}. The rather flat $t$ distributions at large $-t$ shown in Fig. 3 (right) are compatible with a possible existence of an underlying diffraction minimum around $-t \approx 2.5 \text{ GeV}^2$ filled by $t$-resolution effects. These results favor models of hard diffractive production in which the hard scattering is controlled by the parton-distribution-function of the recoil antiproton while the rapidity-gap formation is governed by a color-neutral soft exchange \cite{9}.\cite{10}.
Figure 2: (left) Mean dijet transverse energy for SD and ND events normalized to the SD events; (right) ratios of SD to ND dijet-event rates vs $x_{BJ}$ for various values of $\langle Q^2 \rangle \approx (E_T^*)^2$.

Figure 3: (left) $t_\rho$ distributions of SD RPS data vs $\langle Q^2 \rangle$ for $0.05 < \xi_{RPS} < 0.08$; (middle) slope parameters $b_1$ and $b_2$ of a fit $dN_{\text{events}}/dt = N_{\text{norm}}(A_1 e^{b_1 t} + A_2 e^{b_2 t})$ with $A_2/A_1 = 0.11$ (see text) vs $\langle Q^2 \rangle$; (right) $t$ distributions for RPS inclusive, $\langle Q^2 \rangle \simeq 1$ GeV$^2$ (circles), and $\langle Q^2 \rangle \simeq 900$ GeV$^2$ events (triangles) compared to the Donnachie-Landshoff (DL) model prediction.

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