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Hard diffraction at CDF

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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 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 $t > -4$ 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 $\sqrt{s} = 1.96$ 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, $\bar{p} + p \to \bar{p} + G_{\bar{p}} + X_p$, characterized by a rapidity gap (region of pseudorapidity [1] 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 ($I\!P$) 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 $\mathcal{O}(10)$ 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 my measuring $t_{\bar{p}}$ distributions over a wide range of t and jet transverse energy, $E_T^{\rm jet}$, namely $-t_{\bar{p}} \leq 4$ GeV^2 and $10^2 < Q^2 \approx (E_T^{\rm jet})^2 < 10^4$ 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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[1] Rapidity, $y = \frac{1}{2} \ln \frac{E+p_L}{E-p_L}$, and pseudorapidity, $\eta = -\ln \tan \frac{\theta}{2}$, where θ 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 $\xi_{\bar{p}}$ and $t_{\bar{p}}$ with resolutions $\delta\xi_{\bar{p}} = 0.001$ and $\delta t_{\bar{p}} = \pm 0.07$ GeV^2 at $\langle -t_{\bar{p}} \rangle \approx 0.05$ GeV^2, where $\delta t_{\bar{p}}$ increases with $t_{\bar{p}}$ with a $\propto \sqrt{-t_{\bar{p}}}$ dependence.

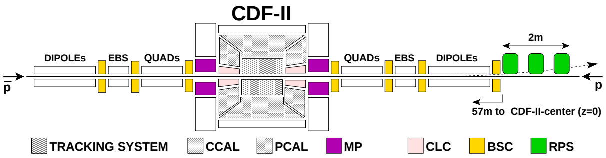

Figure 1: Plan view of the CDF II detector, showing the tracking system and calorimeters (central:CCAL, plug:PCAL, MiniPlugs:MP), the Cerenkov Luminosity Counters (CLC), and the Roman Pot Spectrometer (RPS): EBS are electrostatic beam separators.

Data samples This analysis is based on data corresponding to an integrated luminosity of $\mathcal{L} \approx 310$ 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, or 50 GeV within $|\eta| < 3.5$. Jets were reconstructed using the midpoint algorithm [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 $\xi_{\bar{p}}^{CAL}$. The $\xi_{\bar{p}}^{CAL}$ was then calibrated against ξ obtained from the RPS, $\xi_{\bar{p}}^{RPS}$, 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 $E_T^{jet} \geq 5$ (20, 50) GeV in CCAL or PCAL;
- RPS·Jet5 (Jet20, Jet50): RPS trigger in coincidence with J5 (J20, J50).

3 Results

In Fig. 2, we compare on *(left)* the mean dijet transverse energy between SD and ND events, and on *(right)* the $x_{\rm BJ}$ (Bjorken-x) distribution of the ratio of (SD/$\Delta\xi$)/ND event-rates for various values of $\left\langle Q^2 \right\rangle \approx \left\langle E_T^* \right\rangle^2$ 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 $-t < 1$ GeV^2 fitted to two exponential terms, and in Fig. 3 (right) for $-t < 4$ GeV^2. No significant variations are observed over a wide rage of $\langle Q^2 \rangle$. For $-t < 0.5$ 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 [8]. 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 $-t \sim 2.5$ 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 [9, 10].

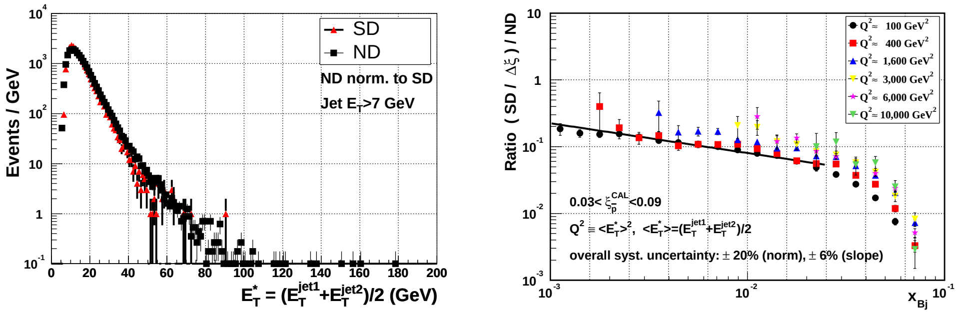

Figure 2: *(left)* Mean dijet transverse energy for SD and ND events normalized to the SD events; *(right)* ratios of SD to ND dijet-event rates vs $x_{\rm Bj}$ for various values of $\langle Q^2\rangle \approx \langle E_T^*\rangle^2$.

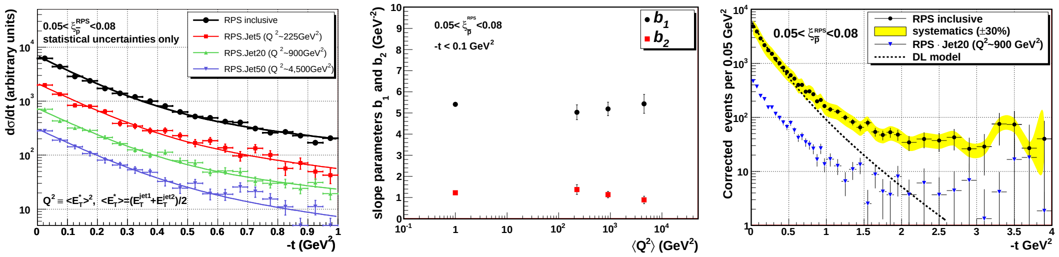

Figure 3: *(left)* $t_{\bar{p}}$ distributions of SD RPS data vs $\langle Q^2\rangle$ for $0.05 < \xi_{\bar{p}}^{\rm RPS} < 0.08$; *(middle)* slope parameters b_1 and b_2 of a fit $dN_{\rm events}/dt = N_{\rm norm}(A_1e^{b_1t} + A_2e^{b_2t})$ with $A_2/A_1 = 0.11$ (see text) vs $\langle Q^2\rangle$; *(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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