New Results on Diffractive t-Distributions from CDF

*Konstantin Goulianos**
The Rockefeller University, 1230 York Avenue, New York, NY 10065, USA

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We present a measurement of antiproton ($\bar{p}$) four-momentum transfer distributions, $t_{\bar{p}}$, for inclusive and dijet single-diffractive production at $\sqrt{s}$ =1.96 TeV at the Fermilab Tevatron $\bar{p}p$ Collider. We use data collected by the CDF II detector equipped with a Roman Pot Spectrometer that measures $t_{\bar{p}}$ and the $\bar{p}$ forward momentum loss, $\xi_{\bar{p}}$. We report results for $0.05 < \xi_{\bar{p}} < 0.08$, $-t_{\bar{p}} \leq 4$ GeV^2, and jet transverse energies, $E_T^{\rm jet}$, of $10^2 < Q^2 \approx (E_T^{\rm jet})^2 < 10^4$ GeV^2. In addition, we search for diffractive dips in both the inclusive and dijet distributions, and compare all results with theoretical expectations.

1 Introduction

We present a measurement of four-momentum-transfer (t) distributions for inclusive and dijet single-diffractive (SD) production in $\bar{p}p$ collisions at $\sqrt{s} = 1.96$ TeV, $\bar{p}+p \to \bar{p}+G_{\bar{p}}+X_p$, where $G_{\bar{p}}$ is a region of pseudorapidity[1] devoid of particles (rapidity gap), and X represents particles from the dissociation of the proton [1]. 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 $G_{\bar{p}} = -\ln \xi_{\bar{p}}$. Using data collected by the CDF II detector, equipped with a Roman Pot Spectrometer (RPS) that measures $t_{\bar{p}}$ and $\xi_{\bar{p}}$ for each event, we extract $t_{\bar{p}}$ distributions for events within $0.05 < \xi_{\bar{p}} < 0.08$. We cover the ranges of $-t_{\bar{p}} \leq 4$ GeV^2 and jet transverse energy, $E_T^{\rm jet}$, of $10^2 < Q^2 \approx (E_T^{\rm jet})^2 < 10^4$ GeV^2, search for diffractive dips, and compare all results with theoretical expectetions.

2 Measurement

Detector. Figure 1 is a schematic plan view of the detector used in this measurement, showing the main detector (CDF II) and the forward detector-components used in the diffractive-physics measurements. The forward detectors 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.

*Presented on behalf of the CDF Collaboration.

[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.

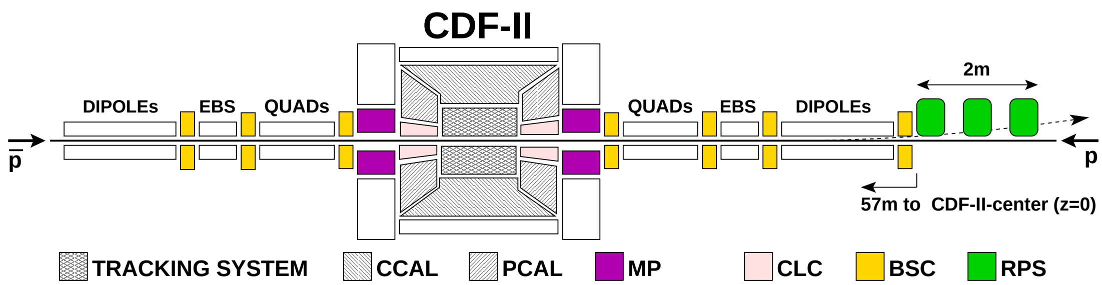

Figure 1: Schematic plan view of the detector, showing the main detector (CDF II) with the tracking system and calorimeters (central, CCAL; plug, PCAL), and the forward components (Cerenkov Luminosity Counters, CLC; MiniPlugs, MP; Roman Pot Spectrometer, RPS). The beamline elements labeled EBS are the electrostatic beam separators.

Data samples. This analysis is based on data corresponding to an integrated luminosity $\mathcal{L}\approx$ 310 pb^{-1} collected in 2002–2003. Events are selected online with a three-level prescaled triggering system, which accepts RPS-triggered inclusive events, as well as jet-enriched events, by requiring at least one calorimeter tower with $E_T > 5$, 20, or 50 GeV within $|\eta| < 3.5$. Jets are reconstructed using the midpoint algorithm [2].

The following trigger definitions are used for measuring $t_{\bar{p}}$ distributions:

- RPS: requires the RPS trigger counters to be in time with a $\bar{p}$ crossing the CDF II nominal interaction region;
- J5 (J20, J50): jet with $E_T^{\rm jet} \geq 5$ (20, 50) GeV in CCAL or PCAL;
- RPS·Jet5 (Jet20, Jet50): RPS trigger in coincidence with J5 (J20, J50).

RPS alignment. The measurements of $t_{\bar{p}}$ require precise alignment of the RPS detectors relative to the actual position of the beam at the time of data collection. We developed a *dynamic alignment* method that is applied offline to the collected data samples. The method consists of introducing offsets in the nominal x and y coordinates of the RPS detectors relative to the beam, fitting data for $-t \leq 1$ GeV^2 with a form composed of two exponential terms,

$$\frac{dN_{\rm events}}{dt} = N_{norm}\left(A_1 e^{b_1 t} + A_2 e^{b_2 t}\right), \tag{1}$$

where N_{norm} is a normalization factor, and iteratively adjusting the offsets until a maximum for $dN_{\rm events}/dt$ at $t_{\bar{p}} = 0$ is obtained. To improve the fits, we set $A_2/A_1 = 0.11$, which is the average value over all data subsamples, and repeat the iterative fitting. This method yields an accuracy of ± 60 μm in the beam position, which leads to a systematic uncertainty of $\pm 5\%$ in b_1 and b_2.

3 Results

$t_{\bar{p}}$ distributions for $-t_{\bar{p}} \leq 1$ GeV^2. Inclusive and jet-enriched data of $10^2 < Q^2 \approx (E_T^{\rm jet})^2 < 10^4$ GeV^2 have been studied. Results for $t_{\bar{p}}-$distribution shapes are shown in Fig. 2

and in table 1. No significant Q^2 dependence is observed from $\langle Q^2 \rangle \approx 1$ GeV^2 (inclusive) to $Q^2 \approx 10^4$ GeV^2. The mean values of b_1 and b_2 over all the data samples are 5.27 ± 0.33 GeV^{-2} and 1.17 ± 0.17 GeV^{-2}, respectively. Systematic uncertainties in b_1 and b_2 are due to RPS-tracker thresholds(1%), instantaneous luminosity (2%), beam conditions (4%), and RPS alignment (5%). These uncertainties are correlated among all data points, and when added in quadrature yield an overall total uncertainty of $\delta b_{1,2}^{\rm syst} = \pm 9.7\%$. The measured slopes of the inclusive sample are in agreement with expectations from the Donnachie-Landshoff (DL) model [3]. The Q^2 near-independence of the $t_{\bar{p}}$ distributions favors 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 [4]-[7].

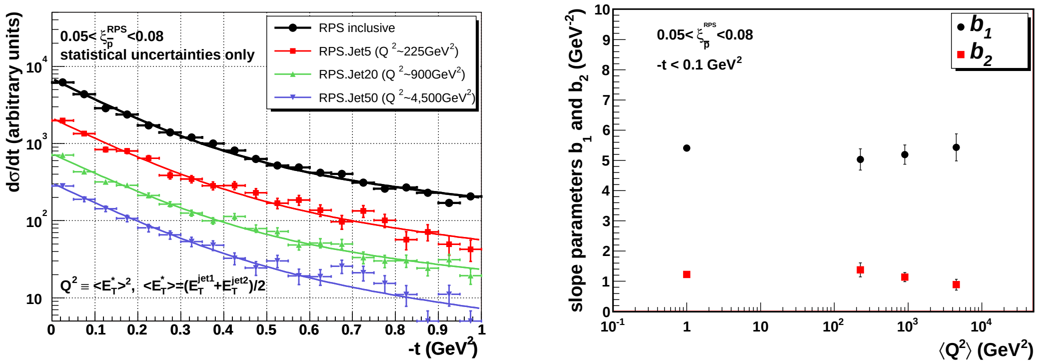

Figure 2: *(left)* $t_{\bar{p}}$ distributions for SD RPS data of various average Q^2 values within $0.05 < \xi_{\bar{p}}^{\rm RPS} < 0.08$; *(right)* the slope parameters b_1 and b_2 vs $\langle Q^2 \rangle$ of a fit to the form $dN_{\rm events}/dt = N_{\rm norm}(A_1 e^{b_1 t} + A_2 e^{b_2 t})$, with $A_2/A_1 = 0.11$ (average over all data subsamples). The RPS inclusive points have been placed arbitrarily at $\langle Q^2 \rangle$=1 GeV^2.

Table 1: Slopes of $t_{\bar{p}}$ distributions of SD RPS data within $0.05 < \xi_{\bar{p}}^{\rm RPS} < 0.08$ for inclusive and dijet event samples of various $\langle E_T^* \rangle$ or $Q^2 \equiv \langle E_T^* \rangle^2$ values obtained from fits to the form $dN_{\rm events}/dt = N_{\rm norm}(A_1 e^{b_1 t} + A_2 e^{b_2 t})$ with $A_2/A_1 = 0.11$, fixed at the average value obtained in the dynamic alignment of all different event subsamples. The uncertainties listed are statistical.

Event sample	$\langle E_T^* \rangle$ (GeV)	Q^2 (GeV^2)	b_1 (GeV^{-2})	b_2 (GeV^{-2})	$b_1/\ b_1^{\rm incl}$	$b_2/\ b_2^{\rm incl}$
RPS	incl	≈ 1	5.4 ± 0.1	1.2 ± 0.1	1	1
RPS·Jet5	15	225	5.0 ± 0.3	1.4 ± 0.2	0.93 ± 0.08	1.12 ± 0.23
RPS·Jet20	30	900	5.2 ± 0.3	1.1 ± 0.1	0.96 ± 0.07	0.93 ± 0.16
RPS·Jet50	67	4500	5.5 ± 0.5	0.9 ± 0.2	1.00 ± 0.10	0.72 ± 0.18

$t_{\bar{p}}$ distributions for $-t_{\bar{p}} \leq 4$ GeV^2 and search for diffractive dips. Figure 3 *(left)* shows $t_{\bar{p}}$ distributions in the region of $-t_{\bar{p}} \leq 4$ GeV^2 for the inclusive and the RPS·jet20 data of $\langle Q^2 \rangle \simeq 900$ GeV^2. The following prominent features are observed: (i) the two distributions are similar in shape, (ii) the inclusive distribution follows the DL prediction for $-t_{\bar{p}} \lesssim 0.5$ GeV^2, but lies increasingly higher than the DL curve as $-t_{\bar{p}}$ increases, becoming approximately flat for $-t_{\bar{p}} \gtrsim 2$ GeV^2. As the $t_{\bar{p}}$ acceptance, shown in Fig. 3 *(right)*, varies slowly in this region, and the overall $t_{\bar{p}}$ resolution at $-t_{\bar{p}} \approx 2.5$ GeV^2 is $\approx \pm 1$ GeV^2, we conclude that the observed flattening-out of the distributions is physics-based, possibly caused by an underlying diffractive dip at $t_{\bar{p}} \approx 2.5$ GeV^2 filled-out by resolution effects.

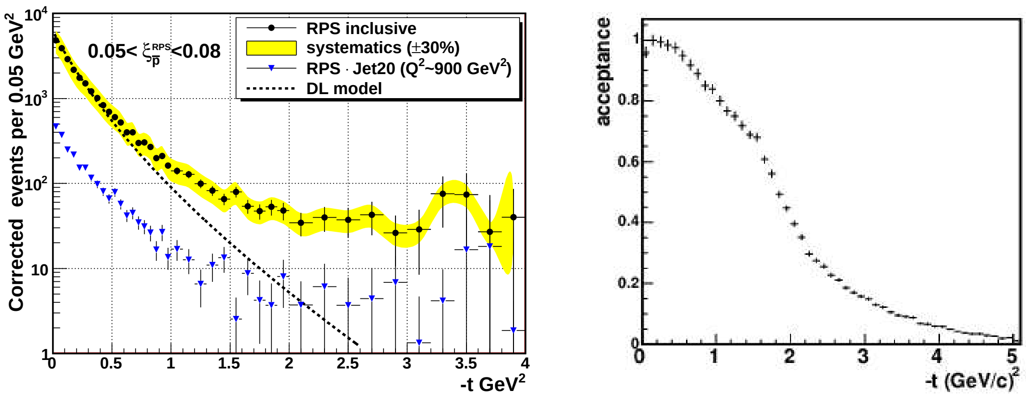

Figure 3: *(left)* t distributions of two data samples of SD RPS events within $0.05 < \xi_{\bar{p}}^{\rm RPS} < 0.08$ corrected for RPS acceptance after background subtraction: RPS inclusive, $\langle Q^2 \rangle \simeq 1$ GeV^2 (circles), and RPS·Jet20, $\langle Q^2 \rangle \simeq 900$ GeV^2 (triangles); the curve is the expectation of the DL model normalized to the RPS inclusive data within $-t \lesssim 0.5$ GeV^2. *(right)* RPS acceptance vs $-t_{\bar{p}}$, integrated over the region of $0.05 < \xi_{\bar{p}} < 0.08$.

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