Update of CDF Results on Diffraction

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(Presented on behalf of the CDF Collaboration)

Abstract. The diffractive program of the CDF Collaboration at the Fermilab Tevatron $\bar{p}p$ Collider is reviewed with emphasis on recent results from Run-II and future prospects.

Diffractive $\bar{p}p$ interactions are characterized by the presence of at least one large rapidity gap, defined as a region of pseudorapidity [1] devoid of particles. A diffractive rapidity gap, which may be forward (adjacent to a leading nucleon) or central, is presumed to be formed by the exchange of a *Pomeron* [2], which in QCD is a color singlet quark/gluon object with vacuum quantum numbers. Diffraction in which there is a high momentum-transfer partonic scattering in the event in addition to the rapidity gap is referred to as *hard diffraction*. In this paper, we briefly review the results on diffraction obtained by the Collider Detector at Fermilab (CDF) in Run-I (1992-1995), present an update of results from Run-II, which is in progress, and discuss future prospects.

RUN-I RESULTS

In addition to measuring $\bar{p}p$ elastic, single diffraction (SD), and total cross sections at $\sqrt{s} = 540$ and 1800 GeV, CDF studied several soft and hard diffraction processes at 1800 GeV, and in some cases at $\sqrt{s} = 630$ GeV [3]. Soft processes studied include:

DD	Double Diffraction	$\bar{p}p \to X + \text{gap} + Y$
DPE	Double Pomeron Exchange	$\bar{p}p \to \bar{p} + \text{gap} + X + \text{gap} + p$
SDD	Single $\oplus$ Double Diffraction	$\bar{p}p \to \bar{p} + \text{gap} + X + \text{gap} + Y$

In hard diffraction CDF measured SD dijet, W, b-quark and J/ψ, DD dijet, and DPE dijet production. Schematic diagrams and event topologies for representative processes are shown in Fig. 1.

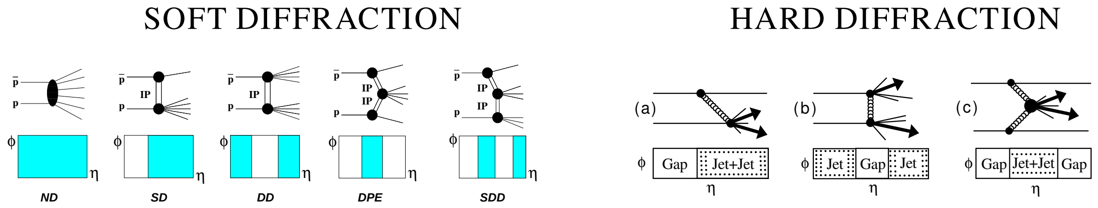

FIGURE 1. Schematic diagrams and η-ϕ topologies of representative diffractive processes studied by CDF. The shaded areas represent regions of pseudorapidity in which there is particle production.

Two types of hard diffraction results were obtained in Run-I: diffractive to non-diffractive cross section ratios using the rapidity gap signature to select diffractive events and diffractive to non-diffractive structure function ratios using a Roman Pot Spectrometer (RPS) to trigger on leading antiprotons. The results exhibit regularities in normalization and factorization properties that point to the QCD character of diffraction (see [3]).

At $\sqrt{s}=$1800 GeV, the SD/ND ratios (gap fractions) for dijet, W, b-quark, and J/ψ production, as well the ratio of DD/ND dijet production, are all $\approx 1\%$. These ratios are suppressed relative to standard QCD inspired theoretical expectations (*e.g.* 2-gluon exchange) by a factor of $\sim$10, which is comparable to that observed in soft diffraction relative to Regge theory expectations. This suppression represents a severe breakdown of QCD factorization. It is, however, interesting to note that except for the overall suppression in normalization factorization approximately holds at fixed $\sqrt{s}$.

Another interesting aspect of the Run-I results is that ratios of two-gap to one-gap cross sections for both soft and hard processes appear to obey factorization. This feature of the data provides both a clue to understanding diffraction and a tool for diffractive studies using processes with multiple rapidity gaps [4].

RUN-II PROGRAM

The goal of the Run-II diffractive program of CDF is twofold: (a) to obtain results that could help decipher the QCD nature of the Pomeron, such as dependence of the diffractive structure function (DSF) on Q^2, x_{Bj}, t, and ξ (fractional momentum loss of the diffracted nucleon), and (b) to measure exclusive production rates (dijet, χ_c^0, $\gamma\gamma$), which could to be used to establish benchmark calibrations for exclusive Higgs production at LHC [5]. Preliminary results from data collected at $\sqrt{s}=1.96$ GeV confirm the Run-I DSF results [3, 7]. New in Run-II are the measurement of the Q^2 dependence of the DSF obtained from dijet production and limits on exclusive production rates.

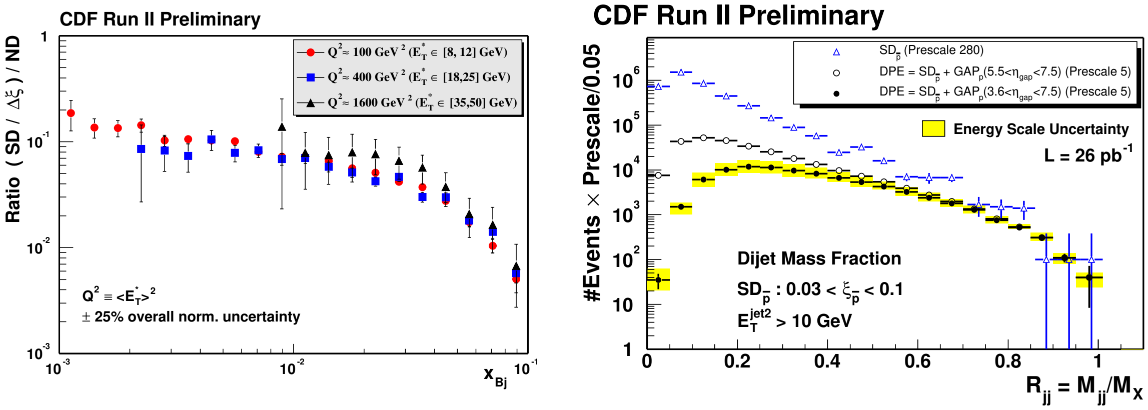

FIGURE 2. (*left*) Ratio of SD/$\Delta\xi_{\bar{p}}$ over ND rates obtained from dijet data at various Q^2 ranges; (*right*) ratio of dijet mass to total mass "visible" in the calorimeters for dijet production in events with a leading antiproton within $0.3 < \xi_{\bar{p}} < 0.1$ and various gap requirements on the proton side: (triangles) no gap requirement, (open circles) gap in $5.5 < \eta < 7.5$, and (filled circles) gap in region $3.5 < \eta < 7.5$.

The diffractive structure function

In Fig. 2 (*left*), the ratio of SD/ND rates, which in LO QCD and at fixed x_{Bj} is equal to the ratio of the corresponding structure functions, shows no appreciable Q^2 dependence. This result was foreseen in the renormalization model [8]. in which the diffractive structure function is basically the low-x ($x < \xi$) structure function of the diffracted nucleon. More data are currently being analyzed to improve the statistics of this measurement.

Data are at hand and analyses are in progress for the measurement of the t, ξ, and flavor dependence of the DSF using dijet, W, and J/ψ production. In addition, factorization will be tested more accurately than in Run-I by comparing the DSFs obtained from dijet production in SD and DPE.

Exclusive production

Exclusive dijet production

The search for exclusive dijet production is based on measuring the dijet mass fraction M_{jj}, defined as the mass of the two leading jets in an event divided by the total mass reconstructed from all the energy observed in all calorimeters. Fig. 2 (*right*) shows M_{jj} distributions for events with different selection criteria. The signal from exclusive dijets is expected to be concentrated in the region of $R_{jj} > 0.8$, with values of $R_{jj} < 1$ being caused by measurement resolution effects and final state radiation. Of course, background events from inclusive DPE production, $\bar{p}p \to (\bar{p} + gap) + JJ + X + gap$, are expected to contribute to the entire M_{jj} region.

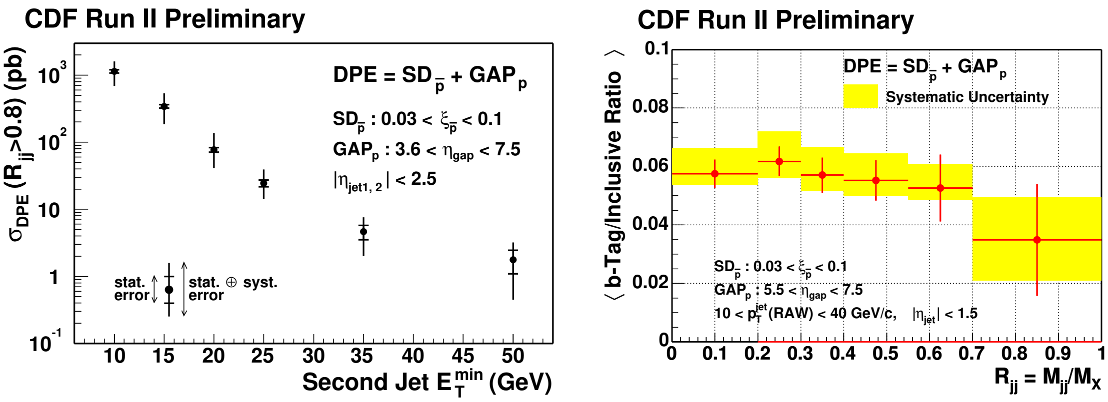

FIGURE 3. (*left*) Dijet production cross sections for $R_{jj} > 0.8$ in DPE events as a function of E_T^{min}, the E_T of the next to the highest E_T jet; (*right*) the ratio of b-tagged to all jets in the DPE dijet event sample versus the dijet mass fraction.

Since no peak is observed at $R_{jj} > 0.8$ in Fig. 2 (*right*), CDF reports production cross sections for events with $R_{jj} > 0.8$, which could be used as upper limits for exclusive production. Figure 3 (*left*) shows such cross sections for various kinematic cuts plotted versus E_T^{min}, the next to leading jet E_T. These cross sections agree, within errors, with recent predictions for exclusive dijet production [5]. Thus, for these predictions to be correct, the background would have to vanish as $R_{jj} \to 1$. While this is guaranteed by the $J_z = 0$ selection rule for leading order $gg \to q\bar{q}$ jets of $m_q << M_{jet}$, Monte Carlo (MC) simulations are used to deal with the dominant $gg \to gg$ process. To avoid using simulations $q\bar{q}$ events could be used to estimate the background and this could be done using dijet events in which at least one of the jets is b-tagged. Figure 3 (*right*) shows the ratio of b-tagged to inclusive dijet events versus dijet mass fraction. A suppression is observed as $M_{jj} \to 1$, as would be expected if there were exclusive dijets in the sample. However, background still may exist from the gluon splitting process $gg \to g + g(\to b\bar{b})$. This background could be practically eliminated if both jets were required to be b-tagged. Presently, more data are being collected with an unprescaled b-tagged dijet trigger to yield a large sample of double-b-tagged dijet events to measure the rate for exclusive production in a low background environment.

Exclusive χ_c^0 production

CDF has reported an upper limit of 49 ± 18 (stat) ± 39 (syst) pb for exclusive χ_c^0 production from a search for $J/\psi + \gamma$ events from $\bar{p}p \to \bar{p} + \chi_c^0(\to J/\psi + \gamma \to \mu\mu + \gamma) + \bar{p}$. Theoretical predictions of ~ 70 pb have recently been revised to ~ 50 pb [5]. More data, collected with a dedicated trigger, are currently being analyzed.

CONCLUSIONS

A comprehensive program of measurements of the diffractive structure function and of exclusive diffractive production is currently under way at CDF aiming at deciphering the QCD nature of diffraction and at providing benchmark calibrations for estimating rates for diffractive Higgs production at the LHC.

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